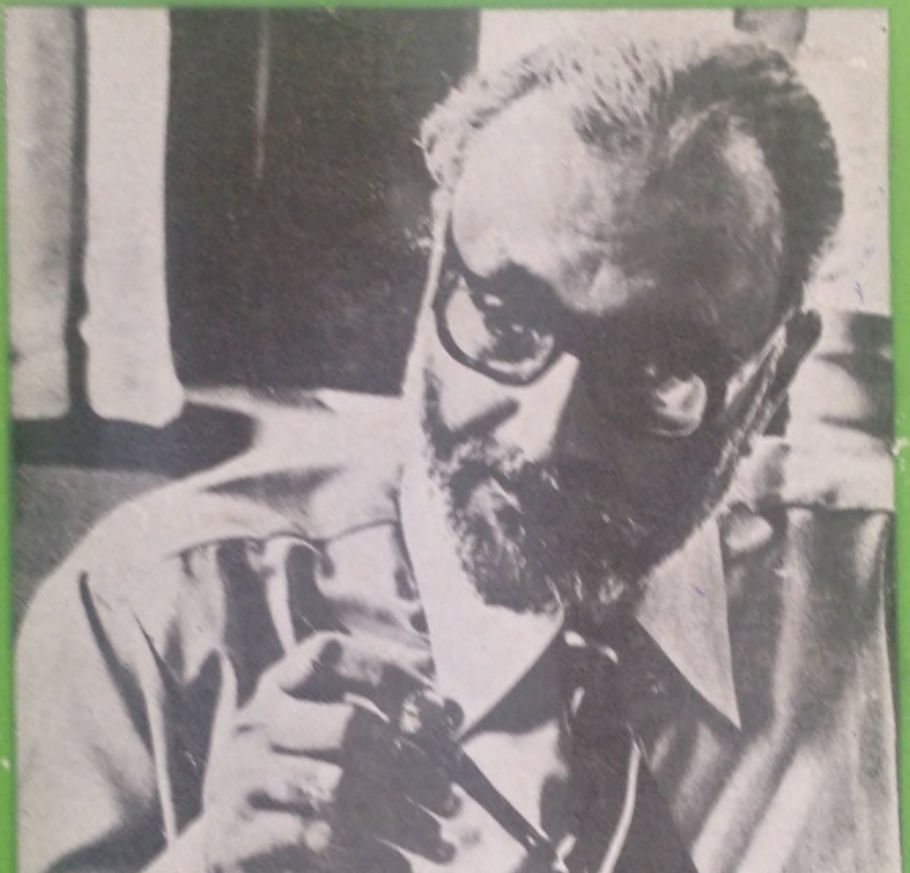
ABDUS SALAM

A NOBEL LAUREATE FROM A MUSLIM COUNTRY

A BIOGRAPHICAL SKETCH

Dr. Abdul Ghani



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by

DR. ABDUL GHANI

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When angels take
The souls of those
Who die in sin
Against their souls,
They say: "In what (plight)
Were Ye?" They reply:
"Weak and oppressed
Were we in the earth"
They say: "Was not
The earth of Allah
Spacious enough for you
To move yourselves away
(From evil)?" Such men
Will find their abode
in Hell—what an evil
Refuge!

Except those who are

(Really) weak and oppressed—
Men, Women, and Children—
Who have no means
In their power, nor (a guide-post)
To direct their way.

Sura Nisāa: Verses 97, 98

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D. O. No. PS/Secy/Inf/81-493

Karachi. November 16, 1981

My dear Dr Sahib,

I have gone through the manuscript of your short biography of Professor Abdus Salam. It is indeed a very commendable work, and I am sure it will prove a great source of inspiration for our younger generation.

Professor Salam's achievements are a matter of pride for all Pakistanis and the lucidity and clarity with which you have presented them in this eminently readable book will be most welcome to a large number of readers who are keen to know more about the life and work of Professor Abdus Salam.

Please accept my most sincere congratulations.

Yours sincerely,

(Ahmad Maqsood Hameedee)

Dr. A. Ghani,
E.I. Thaver Square,
Kahkashan,
<u>Karachi</u>

Acknowledgements

This book is the biography of Dr. Abdus Salam who won the Nobel Prize of 1979 in Physics. The book was mainly written in 1980 and was read in draft by many friends who made many useful suggestions and constructive comments; and I have taken them all seriously and fairly into account while revising the text. For all this help I am most grateful especially to Prof. Ikram-ul-Haque, Mr. Mahmud Faruqui. Commodore Mohsin Pal and Kh. Ziauddin. I would also like to thank Miss Louisa Sossi of the International Centre for Theoretical Physics, Trieste, Italy for providing me the various published papers of Dr. Abdus Salam. My thanks are also due to Mr. A.R. Ghani for his help and interest in the book.

I take this opportunity to record the excellence of the best service I experienced from the British Council and American Centre Libraries in Karachi My greatest debt is to Anees, my wife, and Saadia, my daughter, for all their help with the book, for discussion and support in thinking through the material of the book, their concern that my liberalism may help the vested interests to attack my faith of a Sunni Muslim, and for keeping us all happy and contented at home.

Despite the help I have received, I am responsible for all statements of both opinion and fact in the book.

Abdul Ghani

September, 1981

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Introduction

Professor Abdus Salam has been an extraordinary phenomenon in the scientific horizons of the developing world since the early fifties. In the Third World scientists have watched his achievements with pride, affection and amazement, keeping track of all the glowing traits he has displayed and have their sights sharply focused on his study and on his progress towards the zenith of his glory—the Nobel Prize. I belong to a small group of those scientists who have watched closely the unfolding of his genius and have felt that he might at last take the giant leap which would carve out a niche for him among the scientists who have enlarged man's vision of the vast universe. It is to share this deep-seated admixture of feelings of admiration, affinity and hope in the destiny of the talent of the developing world which Salam symbolizes, that I have undertaken to write about Salam the man, the scientist and a leader of thought and action.

The assessment of a scientist's historical importance is a difficult task. Some few stand out as giants of undiminished stature; many more, famous during their life-times, sink after a a century into comparative obscurity. Born and brought up at an exceedingly backward place in one of the most under-

developed regions of Pakistan, in a rather poor but respectable family, Salam, in his own lifetime, has become a legend for his brilliance and for his subtlety as a spokesman of the scientific development in the developing countries, without any equal or parallel in the whole Muslim scientific history for the last eight centuries.

Salam is the only scientist of the Muslim world to win a Nobel Prize in any science in the twentieth century so far. His work is expressed in the most precise and elegant mathematical language—a discipline considered at one time to be beyond the intellectual horizon of the Muslims of India.

The object of study of the life of Abdus Salam is two fold: one is to keep in mind the question that Salam himself raised: "Are we today firmly on the road to a renaissance in sciences—as the West was in the 13th century at the time when Michael left Scotland in 1217 A.D. to study at Toledo in Spain with the ambition of introducing Aristotle to Latin Europe, by translating from the Arabic texts then taught in Spain?".

The task of a religion is to develop the consciences, the ideals and the aspirations of mankind. The object of science is to achieve and realize in practice the aspirations of mankind by developing, without prejudice or preconception of any kind, if possible, a knowledge of the facts, the laws and the phenomena of nature. The problems of creating a great Muslim society are immensely greater than many of us are being taught and led to believe. We would have been better equipped to deal with them if we had identified and understood their correct nature and the magnitude of the difficulties involved. Abdus Salam has attempted to identify these problems by emphasizing that science is the mainstay of modern economic, social and political thought with a firm belief that a true science can never contradict a true religion—a belief that has established tolerance in the western civilization by strengthening the value of free thought through the provision of scientific freedom to study, think and discuss all subjects, including religion.

By remaining a deeply religious man in his personal life—a man who has an abiding faith in Allah, in the true Islamic values of temperance, of goodness, of tolerance, Salam has sought to show, like some other leading scientists, that great science is compatible with great religiosity in a personal sense.

He has taken pride in his Islam as he understands it. Not only that, Salam has tried to emphasize that it is the duty of a Muslim to study Sciences.

Salam is fully cognizant of the fact that the revolutionary, scientific and technological developments from the 17th century onward have been exclusively a Western development.

He has, however, continued to emphasize that the scientific foundations on which the Western World built its science and technology arose from the Muslim scholars' contributions that existed up to the 13th century. The Muslims have hardly as yet contributed to this industrial and technological revolution—and as the question as to why this has happened has still no agreed-upon answer, the study of the life of Abdus Salam takes on a new meaning in this context.

The second object of recording the main facts and writing about his work is that they may be of some interest to the general reader. I have personally little faith in any peculiar gifts of a genius. I believe that the basic differences between human intellects are considerably smaller than are generally made out to be. However the details of the life of Abdus Salam are of interest and value because they illustrate the remarkable progress of the development of a human mind from an undeveloped country in science. It is hoped that a study of the life of Abdus Salam may bring out qualities which combine to create a great scientist and a towering scientific sage; as coming together of many qualities and many conditions are essential to produce a man like Salam, and by a deep analytical thought it may become possible to foster more such scientists and such sages.

By identifying and providing the conditions in which such extraordinary talents can grow, one may wish to start a renaissance in sciences in Muslim and other developing countries. At least it is necessary to try to quantify the qualities and conditions so that the emergence of such a genius is, as far as possible, not left to chance or accidents in underdeveloped lands. This was the motivating force that led me to write this book.

It was in 1964, while screening the world scientific literature to compile the Muslims' contribution to science since the Industrial Revolution, when it dawned on me that Salam's scientific contributions are unparalleled in Muslim history and

so I wrote to Salam to publish the collection of all his works in a book form. The realization that there has hardly been any scientific contribution of the Muslims to the world knowledge of science and technology during the last eight centuries became very painful. I started looking for the explanation. It seems that in a Muslim society old unscientific ideas give way imperceptibly with time. They have become strong habits and deeply ingrained mental attitudes of bias and hatred. The lack of scientific culture has made the Muslim people disorganized, incoherent and without any real faith in the possibility of changing themselves or the world around them. Their stances and positions are hardened by their past laurels, and they are confused with questions of faith, prestige and subtle academic polemics. They usually develop reactions which are advanced as assertions of principles on which they refuse to yield. They completely forget that a true science will never contradict their religion—a true religion, and therefore continue to reject tolerance and freedom to scientific thought in their societies.

The present-day Muslims think in one way, speak in another and act disjointedly in a third—the whole process being un-Islamic and un-scientific. They, however, verbally accept Western standards of economics, technology and science but claim to despise much of their social outlook. I, for one, will agree to exchange our mass-scale poverty, disease, corruption, nepotism,, unemployment and inhuman treatment that exist in the Muslim world with western society's tensions and pressures, frustrations, frequent divorces, homes for old people and occasional suicides. There is a general realization that the corruption, the poverty and the hypocrisy among the Muslims are not due to any law of nature but are the products of their particular social structure, devoid of scientific culture, which they themselves have erected to live in.

When Professor Abdus Salam was honoured with the Nobel prize for Physics in 1979, a few persons approached him for the "early publication of his various writings including scientific papers, as well as the popular articles relating to his works and thought".

Professor Abdus Salam wrote to me: "I would appreciate your comments on the attached proposals". I wrote back: "I am not in favour of publishing the collection of the publication

of your technical papers on two grounds—Firstly your work has been internationally recognized with the award of the Nobel Prize, and secondly who in Pakistan would understand the significance of the original contributions of your scientific work. I would suggest that a book on the: 'Achievements of a boy from Jhang' along with your life-story, your experiences in Physics and in an alien industrialized society must be narrated to educate and inspire the youth of the Muslim and the underdeveloped countries. The book must have an appeal and attraction to the widest spectrum of people in the Third World countries". While writing this to Salam I did not have the wildest dream that I would agree to take on and complete this book. I hope and pray that the readers may find it informative and inspiring.

Ancestors and Childhood

As was customary in those days Abdus Salam, the first child of his mother, was born at Santokdas, Sahiwal, in the home of his mother's parents on 29 January 1926. His mother's father Hafiz Nabi Baksh—a *Hafiz* of the Holy Book—was serving there as a "*Potwari*", a minor but resourceful functionary of the revenue department of the Provincial Government of the Punjab.

Whether Salam was born a genetically genius destined to make history is a moot question which defies any simple direct answer. To assess even the quality of genes the parents transmit to a child, all that is possible to attempt is to review the salient characteristics of the child's parents while reflecting on the difficulties of discrimination between intellectual potentialities and life attitudes determined by genes and those determined by education and environment—and environmental factors may include the effects of cosmic radiation that vary with time and place.

Genes, education and environment coalesce constructively to produce a rare design usually called a genius, and the flowering of a genius is, of course, through ninety-nine per cent of perspiration and one per cent of inspiration.—and this seems to have happened in the person of Abdus Salam.

Abdus Salam's parents, Chaudhry Mohammad Hussain and Hajira Begum, lived in a small market town Jhang, some 200 km. northwest of Lahore. Jhang district was considered to be one of the most remote and underdeveloped farming area of the Punjab in British India. It was chiefly known for "*Hir and Ranjah*"—a legendary love story narrated and depicted in the feudal setting of its countryside. The family with ancient traditions of scholarship and religious learnings have lived in Jhang for many generations tracing its line to Bhatti Rajpoot princelings converted to Islam by a Muslim mystic about the year 1200. Abdus Salam's father's father, Mian Gul Mohammad, a religious scholar and a respected local "*Hakim*" in Jhang town, had two sons. The elder son, Ch. Ghulam Hussain, about seventeen years senior to Ch. Mohammad Hussain, was a bright student and stood first in eighth and second in tenth class examination of the Punjab University. After graduating from Forman Christian College, Lahore, he entered the Provincial Education Service and retired as District Inspector of Schools in 1932. He was the first member in the family to embrace the faith of an Ahmedi Muslim. It was his daughter, Imtul-Hafiz Begum, whom Salam married in 1949.

Ch. Mohammad Hussain was born on 2 September 1891. There is little information about his performance in school. Probably it was normal like that of any other boy of Jhang. However, after completing his studies in Jhang, he left for Dera Ghazi Khan where Ch. Ghulam Hussain was then serving as an Assistant Inspector of Schools. In 1913 he joined Islamia College, Lahore, for his B.A. but somehow he could not succeed in getting his B.A. Degree though he stayed on in Lahore for five years, until 1918. While a student at Islamia College, he joined the fold of Ahmedia Community in 1914. Ahmedia Jamaat, at that time, abhorred the philosophy of *Jihad* of the sword and preached peace, alegiance and loyalty to the Government of the Day. This produced strong social protests and displeasures of the majority of the Muslims in the Punjab. Under these conditions Ch. Mohammad Hussain's conversion to Ahmedia Jamaat indicated in his character a spirit of enterprise and his defiance of the public opinion. His elder brother must have had some inspirational influence on him for this change but he met a strong disapproval from

the other members of his *biradari* (kinsmen). These conflicting pressures of society fostered anxiety, strain, sensitivity and insecurity in him and in his family, however their religious zeal, the unity and discipline of their community opened the way for the fuller development of their mental capabilities.

Ch. Mohammad Hussain was scrupulously honest and fastidiously clean in his personal life. Being kind and considerate he had a congenial character with pleasing manners. He was a religious person who was respected by all who came in contact with him for his piety. At the same time, he tried to do his duty conscientiously, was decent, had tremendous self-respect and moral courage—the readiness to stand up for what he believed to be right. He was more cultivated than most men at that time in Jhang. He stimulated simplicity, tenacity and self-confidence among his children to achieve their goals.

He took his first job as temporary "English teacher" in Government High School, Jhang, in 1920, teaching science, mathematics and English to ninth and general knowledge to tenth class students. Later on, he obtained the position of Head Clerk in the education office of District Board, Jhang.

He got married first in 1920 at the age of twenty nine to Saeeda Begum who died in child-birth on 30 April 1922, having delivered a daughter named Masooda Begum. This was a traumatic experience for Ch. Mohammad Hussain. It struck deep in his person and turned him even more to prayer. The helplessness of seeing himself widowed after two years of marriage and the added caring responsibility of bringing up a baby daughter solicited soul searching and fervent prayers for a fruitful future life. Every man has desired in various shades, to have a son but what Mohammad Hussain prayed for now was to have a son in whom he could invest and work on to develop a great man to nullify his own image of failure in life.

Chaudhary Sahib once told me, while we stayed together in Swat in August 1965, that with this desire he prayed and begged GOD to supplement his impoverished life with another spouse who could give birth to an illustrious son of unique intellectual capabilities. And he persisted in his prayers until he got remarried on 12 May 1925 to Hajira Begum. His belief in his prayers according to him, was rewarded when on 3

June 1925, during evening prayers, he had a vivid perception that a son would be born to him and he selected his name to be Abdus Salam. Then he had six more sons and a daughter. Who can say that a child born out of love, longing and prayer has the greater probability of inheriting superior genes than others born less solicitously.

For his son, Salam, Ch. Mohammad Hussain became an exceptionally unusual man as he desired for his son a successful and lucrative career in the Indian Civil Service and this led to meticulous care for the health and well-being of the baby. It became a case of low living and high-thinking. With total faith in the destiny of his son, he devoted his full attention to secure a sound education and superb training for Salam.

It became his life's mission, through persistent concern and ardent desire, to see Salam excel in studies—a desire that transmuted various accidents in Salam's life into unique opportunities for him to develop and advance in life. Astonished by the magnitude of the efforts that the father made, it seems that intuitively he knew that "he who struggles with joy in his heart, struggles more keenly because of that joy". It was obvious to the father that the system of education prevalent at that time had deprived the country of the services of many potential top-class academicians and leaders from the poorer ranks of society. He, therefore, became more concerned to avoid the possible pitfalls the child might encounter along his way to sound education. Therefore, on priority basis, the parents concentrated their attention on building robust health of the baby and that is how the baby won the first prize at the age of two for being the healthiest child in Jhang town.

Then his mother taught him to read and write before he went to school. So he was trained and disciplined at home to make him catch up with the children advanced in age. As a matter of fact, the child was not born in a primitive society in the sense of the expectations already held by his parents. The mother gave him a sense of security and of being loved, allowing him as much freedom as possible for environments to proceed with his education.

Salam's mother was a much simpler character. She too had descended from the very core of a fervently religious family. Her elder brother had been a Muslim missionary in what is

now Ghana and Nigeria for over twenty years, making tremendous personal sacrifices for the sake of propagation of Islam. Hers was a humbler intellectual background than that of her husband. She was from all accounts a sweet and gentle woman who provided her son the uncritical and measureless love and stability that comes more easily from a simple heart.

She was a fundamentally contented woman, with the contentment that is squarely based on the love of her family, love of her religion and the simple truth that it is better to be good and kind than the reverse. It was perhaps from his mother that Salam inherited his looks.

His father would tell him many exciting stories of fiction, adventure and Islamic history. He would subsequently ask the child to narrate them so that he could retain and grasp their essence, and could cultivate the qualities of a good speech.

The father would assist Salam to place emphasis on appropriate statements with correct change of pace and of pitch, and the right use of pauses. A stage came when father had to search for new books to narrate stories to the child as he would not listen to ones he had already heard. This approach developed a keen interest in the child to read books and magazines with his own effort. So the father became responsible for cultivating in the child an appetite for studying widely and retentively. The young Salam was urged to write out the summaries of the stories he read by acquainting him with hard practice which made composition easy for him as he learnt to write down his thoughts quickly and fluently. He made good use of his time and formed habits of work that have lasted throughout his life. Ever since his mental appetite has remained insatiable.

He was sent to M.B. Middle School when he was six and a half years old. The Headmaster Mirza Ghulam Abid who was personally known to Ch. Mohammad Hussain accepted Salam in the fourth class without making him take the requisite test and Salam got off to a tremendous start with his father's enthusiasm, good health and passing the fourth class at the age of eight. So his great talents were successfully launched before the age of seven. While in school, the father would encourage him to write articles for the children's magazine in the local paper. Evidently, a happy and successfully culti-

vated infancy was of decisive importance in his life-history. He provides evidence for the claim that rearing and education up to the age of seven determine the character. He never developed boyish tastes. He showed no faults of youth.

The boy possessed an immensely retentive memory. While in his fourth class he committed to memory multiplication tables up to forty. He also learnt numerous long passages and historical quotations of eminent men by heart to write essays and to annotate. As a child he started studying the Quran with translation and that is how he took Arabic as an elective subject in his matriculation curriculum. His school report for the year 1934-36 recorded: "Abdus Salam stood first in the fourth class examination held at the Jhang Centre in March 1934. Got first prize in penmanship at the Educational Exhibition held in March 1936 from D.C. Jhang." His report of VII class contained: "Stood first in the first aid class held in July 1937. Got first prize in penmanship and in map drawing at the Educational Exhibition held in March 1937."

The father would take Salam on bicycle to visit ginning factories, dams, bridges and railway steam engines and would instruct him after the visit, to learn more about them by studying the relevant library books. In his span of studentship the main benefit he derived not so much from listening to lectures and swotting up the textbooks, but from studying books which were not prescribed reading.

He was helped and encouraged to prepare his lessons before they got taught at school the next day. The principles he imbibed and the habits he formed under the guidance of his father determined the character of his life. His father was responsible for generating in Salam the desire for the limelight. He was given a start in life with all the gifts, an excellent brain, extraordinary attention and a strong physique. He developed a deep self-confidence in his ability to achieve his targets. Through a retentive memory he also cultivated powers of reasoning based on keen and enlightened observations.

He passed his eighth grade by standing first in the district and fifth in the province at the age of twelve in 1938 securing 591 marks out of 700. This year he won a prize of two rupees for Album at the Exhibition. His Headmaster

recorded, "the best and the most brilliant student I have ever taught in my life". Winning a scholarship of rupees six a month he started supporting himself in a small way, though not completely. He studied at Government Intermediate College, Jhang, from 9th to 12 Class. According to his father, there was a tough competition with a few non-Muslim boys in matric in the college and so the father got all the school text-books in mathematics that were available on the market and asked Salam to work out all the problems listed in those books under his direct supervision. But when Salam stood second in the term examination of the school, the father reminded him of the story of Qutub-uddin Aibak who when defeated by Pirthavi Raj got his army general to be fitted with the horses' grain basket and asked him if he (Salam) should also be treated in the same way.

Probably this was the beginning and the end of Salam's lassitude as from that day onward he stood first in all the examinations he took in Pakistan. When his father was told that the child should not have been forced to study long hours and subjected to worries and anxieties as he might have broken down under too heavy a burden, the father replied that the son of a proud Muslim Rajpoot family was expected to struggle and win in a scholarship from his competitors. One has to ascribe great importance to Salam's early upbringing and the strict principles his father inculcated in the formation of his particular mental habits. Salam drew inspiration from principles which recognize the immediate influence of a supreme power as a guide in the conduct of life and encourage feelings of self-confidence and pride in the achievement of intellectual as well as moral triumphs. A sense of commitment and hope released Salam's creative energies and generated the will for hard work while drawing much sustenance from a wholesome family life. The father regularly monitored the progress of the boy in the school. Before the matriculation examination he made a perceptive analysis of Salam's educational attainments and concluded that the boy was relatively weak in science practicals and Arabic language. It further revealed that the college couldn't care less for the boy to stand first in the matriculation examination of the Punjab University. This sent the father crusading to all the teachers concerned, intellectua-

lizing and emphasizing the benefits the teachers and the college would derive, if his son topped the University list. So the teachers agreed to provide the extra guidance to the boy in building up his proficiency.

The father urged the child to practise extensively in Essay-Writing and solicited the comments of the local writers particularly the renowned poet Sher Afzal Jafri of Jhang for improving the quality and style of Salam's writings.

At the intermediate level at Government College, Jhang, the father approached the principal for advice on the quality of the essays that Salam had written. The principal advised that Salam should restrict his tendency of quoting extensively the passages of other writers in the main body of his essays.

In his second year at Jhang College, Salam became the Editor of the College magazine "*The Chenab*" and wrote an article establishing the date on which Mirza Ghalib changed his "nom de plume". This article appeared in print in "*Adabi Dunyia*"—a front-rank Urdu literary magazine—in 1943. Salam has always felt proud of this article which represents high traditions of literary search, scholarship and taste.

In 1942 Salam joined Government College, Lahore, for his B.A. degree—the premier college of the Punjab. His father was then working as Head of the office of the Inspector of Schools of Multan Division, at Multan. Salam could have joined the degree College at Multan and stayed at home. But the advice of all friends was that he should join the best college and get the best education. So he joined Lahore as a boarder at the New Hostel at the age of sixteen. His father accompanied him to Lahore when he was due to appear before the admission board of Government College.

At Government College Lahore, during his B.A. studies, Salam started to spend some time in playing chess in the hostel where he was living for the first time, away from his own family. Since Salam was the hero of the Muslim students, from his matriculation examination results onward, his fellow Muslim boarders worried about his performance in the B.A. as against the Hindu and Sikh competitors and wrote to Salam's father. When this news reached his father, he was distressed and advised the boy to stop wasting time with a reminder of keeping his life's goals in focus. The boy not only stopped

playing chess but also started putting in concentrated hours of study, near the examination, by getting the door locked from outside to avoid interferences from other fellow students of the New Hostel.

During the college days in his third year, Salam found a number of his friends appearing for an interview for Superior Railway Engineering Apprenticeship Scheme. Salam too appeared for the competition, and was selected. He never seriously desired to consider this for a future career; for one thing the glasses, which he had worn since before his matriculation, would have made him ineligible for the Railway service. After the selection Salam declined to join the service.

During those days there was no Semester System and there used to be perfect discipline in the examination halls. Hardly two percent of the students used to get first class marks, which meant more than 60% in aggregate, in the University examinations.

By all standards Salam proved himself to be a prodigy as he stood first in all the University examinations from matric to M.A. securing the highest recorded marks in the Punjab University, in the matriculation and the B.A. examination. In his B.A. he topped the lists in each individual subject of study—English, English literature (for honours) as well as pure and applied mathematics. In the University's history he was the second boy to top the list in all its examinations. His topping the list and creating a new record in the matriculation (Roll No: 14888) was a sensation since the matric examination was considered then a communal tug of war between Muslims, Hindus and Sikhs which Muslims invariably lost. The other person to have this distinction was Hafiz Abdul Majid who became an ICS and retired as a senior civil servant of the Government of Pakistan. A third genius who revealed the potential for recognition in the mathematical world was Inayat Ullah Mashriqi. He also got allured by the Indian Civil Service but later on resigned to start *Khaksar* Movement in British India. At Government College, Lahore, Salam served as Editor-in-Chief of the College magazine and also as President of College-Union.

The prospects for a talented young scientist in the subcontinent were bleak as there existed no situations in the

government and no position in society to which hope can point or to cheer him in his laborious path. The work could neither be valued nor trusted in the gutted slums of the world civilization. The situation has hardly improved till today and is likely to remain this way in the future because of sub-standard leadership in an under-developed society of men. So with a practicality of mind what the father desired for his son was first the education he could secure, and then an entry into the Indian Civil Service, the Core of the bureaucratic Establishment, and the steel-frame of British Raj in India. Having failed to get a degree for himself, like Motilal Nehru who also aimed for Jawaharlal Nehru to join the Indian Civil Service as a first Kashmiri Pundit, he encouraged Salam to win academic distinctions before sitting for the competitive examinations for recruitment to the Civil Service. This was more for the prestige and power which membership of this service carried than for the financial rewards it directly offered. Salam also became convinced that the life of an ICS was the most rewarding of all professions and, therefore, he targeted to prepare himself for becoming one by standing first in its competitive examination and to become the senior most official of the batch of that year.

Normal work of the classes was considered insufficient for him as he read widely and methodically. By the time he completed his M.A. degree, he was an accomplished scholar in his own surroundings and had shown plenty of ability for independent thinking. In addition to his mathematical studies he was well versed in philosophy, had read fairly widely in Islamic history, and acquired working knowledge of economics and political science. Each book that gave him a new and wider horizon left an indelible imprint on his mind. He became a man of ambition and character determined to achieve new heights in life. Salam wrote his first mathematical paper in his fourth year in 1942 on "A Problem of Ramanujan". It was published in *Maths. Student*—Vol. XI, Nos. 1—2, March—June 1943. In this paper Salam advanced a simple technique for solving a particular set of equations eliminating the laborious method worked out by Ramanujan.

ABDUS SALAM'S ACADEMIC ACHIEVEMENTS IN PAKISTAN

Examination	Year	Subjects	Position	Scholarship Won	Marks Obtained
8th Class	1938	Science & Arabic	First in Jhang Distt. ...	Rs. 6/- a month.	591 out of 700
Matric.	1940	Science & Arabic	First in the Punjab University. New Record	Rs. 20/- a month (Govt. scholarship) Rs. 30/- a month (Ahmediyya Jamaat scholarship).**	765 out of 850
F.A.	1942	Physics, Maths. & Arabic ...	First in the Punjab University.	Rs. 30/- a month (Govt. scholarship) Rs. 45/- a month (Ahmediyya Jamaat scholarship).**	555 out of 600
B.A. ...	1944	Mathematics A & B Courses & English Honours. ...	First in the Punjab University. New Record. 1st in each individual subject (English, Mathematics & English Honours)	Rs. 60/- a month (Govt. scholarship) Rs. 60/- a month (Ahmediyya Jamaat scholarship).**	451 out of 500
M.A. ...	1946	Mathematics	First in the Punjab University. ...	Rs. 550/- a month (Punjab Govt. scholarship for studies abroad at Cambridge.)	573 out of 600

** The Ahmediyya Jamaat Scholarships were announced for the first time at the Ahmadiyya Jubilee in 1939, to be awarded on the basis of talent if the scholar won 1st, 2nd or 3rd place in the University, Salam was the first (and of the few) to qualify.

CHAPTER II

The Crucial Period (1946-1954)

In 1940, on account of the second world war, the first accident that Salam has talked of that turned Salam to science, the annual competitive examination of the Indian Civil Service was suspended for an indefinite period depending upon the final conclusion of the war and the resumption of normality in international relations. In 1944 when Salam won his B.A. degree by securing the highest marks ever recorded, it became objectively prudent for Salam to consider a second choice of career for himself as the war had not then ended. With this consideration of flexibility Salam, although good at English Literature, was advised to take up Mathematics in his M.A. Course so that it may lead him to scientific research. It was widely known that mathematics was not a particularly happy choice for the Civil Service examination, but the new situation demanded a preference for Mathematics. However when in 1946 Salam again topped the list in the university in his M.A. examination by securing five hundred and seventy three marks out of a total of six hundred, a reappraisal for the future course of his life became essential, as the British Government of India had decided to hold the competitive examination in 1947, still an year off from 1946. During this period Salam's restless

father continued to solicit and seek advice from the Muslim academicians in the Punjab as to which career Salam may be advised to launch on.

There was no indigenous scientific cadre or community at that time. The Indian scientist was a member of the scientific community of the United Kingdom and his activities were mostly guided and evaluated by his ability to contribute to that community. As the maximum age for entry into civil service was twenty-five years, it was advisable for Salam to keep his options open and to pursue, if possible, higher studies abroad. During the process of these consultations, Salam's father also approached Mian Afzal Hussain, the younger brother of Sir Fazal Hussain, one-time Chief Minister of the Punjab.

Mian Afzal Hussain, who was Vice-Chancellor of Punjab University when Salam had first become famous in 1940 with his Matriculation Examination result, had kept in touch with Salam and his father all this time. He it was who advised Salam to go to Cambridge for part II Mathematics Tripos and not to get direct admission to a Ph. D. Course in England as was usually done by majority of the Indian Students holding M.A. degrees from the subcontinent. He emphasized that before one started working for a Ph. D. on the frontiers of knowledge where theory sometimes becomes a doubtful guide, it was essential and indispensable to take a clear-sighted look at the frontiers to become aware and to identify the problems one was expected to tackle.

While Salam made himself available for any challenge that came along and was quite capable of coping with it, his father was in a fix. as he could not afford to send Salam abroad for further studies. He could not even demand from the Government the opportunity that was its obligation to provide to his son who possessed such a unique academic record. Probably that is why Salam has talked about the three "main accidents" that turned Salam into a research scientist. In this context he emphasises that Societies of developing countries have failed, in varying degrees, to establish a rational system where everyone may get the opportunity to develop his or her talent to its maximum potential. And this is the explanation of "accidents" which assisted all great men to survive for humanity, while

there were many others who got lost in the absence of coincidences of accidents in their lives. And these IMPERFECTIONS and shortcomings of our systems belie our claim that we live in a scientific-age; as in reality, we merely want science to serve our material needs without inculcating the discipline of scientific logic and thought in our public and social actions.

The turning point in Salam's life came with the help of a person named Khizar Hayat Tiwana, a unionist and one of the biggest fuedal landlords of Sargodha District in the Punjab. He never encouraged or promoted education in his own Kahlra Estate where thousands of farm labourers worked on his land spread over tens of thousands of acres.

Khizar Hayat collected funds to the tune of rupees one hundred and fifty thousand to support the British war effort; but the war ended in 1945. He became the Chief Minister of the Punjab in Coalition with the Congress Parliamentary Party in 1946. As the funds were left unutilized he decided, probably under advice from a senior civil servant, to institute scholarships for Small Farmers' Sons for study abroad. To restrict this benefit to small farmers' children, the condition imposed was that a farmer's land revenue-tax must not exceed rupees twenty-five a year. In order that Salam might qualify to compete for this Scholarship, his father obtained the desired certification from the Deputy Commissioner of district Gurdaspur, where Salam's father owned a small piece of land given to him by his brother who was now living in that district (the second "accident" in Salam's life).

Salam had no difficulty in winning the scholarship along with these other scholars. The scholarship was for a duration of three years at the rate of 'pounds' 375/- a year. The exchange rate at the time was about thirteen rupees to a British pound. Salam, on the advice of his teacher Mr. Abdul Hameed of Govt. College, Lahore, and because of his extra perception and anticipation, had taken good care to apply to Cambridge simultaneously. While the other scholars were promised admission for the subsequent years, Salam received a cable on the same day he won the scholarship, 3 September 1946, saying that an unexpected vacancy had come up at St. John's College. Prof. Dirac, who had won the Nobel Prize for Physics in 1933, for his outstanding work in quantum mechanics, lived and

worked at St. John's College. Salam was asked if he could join the College in October. The next hurdle was to get a passage at a time when most English families were hurrying back to England in anticipation of India's freedom. Salam was advised to remain available at Bombay and wait on the off chance that he might get a departing ship. As it was, Salam was lucky with the very first vessel SS "*Franconia*" which left on 8 September carrying about 600 Italian prisoners-of-war and some 600 English families.

Cambridge, the greatest seat of scientific learning in U.K., had the extra experience and wisdom to identify and nurture talent in its characteristic time-honoured traditions. So it was natural for Cambridge to spot Salam's unusual potential and offer him admission at short notice. However it still needed an unfilled place for him which somehow turned up. It was lucky that he left that September, 1946, for in the following year came Partition, and with it the scheme was cancelled for the other three who could not leave in 1946 (the third main accident Salam had talked of). Salam's father always said that the entire exercise of Khizar Hayat Khan to collect the war fund was designed for one purpose—to send Salam to Cambridge.

Salam went to Cambridge in October, 1946, quite self-confident, and suitably satisfied with what he had already achieved. He was fully aware that he had reached a new world where he must move fast to remain at the top. On the other hand, there was also the realization that he was paying the price of three years' precious time of his life for being born in an under-developed society. Had he been born in England, he would have done his Tripos from Cambridge in 1946, the year he was going to commence his studies for Part II mathematics in Tripos. Salam recalls that the first person who met him at the Liverpool docks when he got to England was Sir Mohammad Zafrullah Khan, then member of the Viceroy's council, who had come to fetch a relation of his travelling on the same boat. Sir Zafrullah gave the shivering Salam a spare great-coat to protect Salam from the biting English cold.

It was Salam's first experience at Cambridge to learn at the frontiers of knowledge from those who were themselves engaged in advancing it. He found that the lecturers never attempt-

ed to cover a subject comprehensively as the students were expected to fill the gaps with their own reading. Hardly anything got left out for being outside the prescribed syllabus.

Cambridge captivated him. It added a further spur to his ambition to make his mark and to justify the expectations of his father and all his well-wishers. He plunged into the exhilarating atmosphere of the University with a mixture of excitement and ambition.

He had clearly made up his mind to succeed without allowing himself to be influenced by a different social structure in England. Salam recalls that, during the study of his intermediate Physics in Pakistan, he could not comprehend the concept of "stress" and 'strain' as the author of the book, that he studied, was himself confused about it; it was later on that he, on his own, disentangled the fact that 'one is the cause and the other is the effect'. At Cambridge Salam found the style of the lectures not very different from the ones he had already experienced at the undergraduate level, though he was most influenced through the tutorial system of Cambridge where a tutor would come out during the middle of the year with a ten-year old examination paper and would ask the student to solve it! At Cambridge with many of his teachers Salam formed lasting friendship and remained in close contact with most of them in later life.

Sir Edward Appleton, Nobel Laureate of 1947 for his investigations of the physics of the upper atmosphere especially for the discovery of the Ionosphere, wrote of Cambridge of the 1920's that there were three ways of being unpopular in Cambridge. These were:

> "to be known outside Cambridge, to know something about a subject other than that which you had taken in your degree examination and to be able to write simple English which anybody could understand".

Salam, however, believed that he could afford to think that an exclusively scientific training brought about a mental twist as surely as an exclusively literary training. He decided not to be a lopsided man, he was of the view that a man who devoted his life to one science or interest was unlikely to have significant imaginative deductive ideas. The fertility of mind, for him, gets sterilized by a monoculture. The mind, like the earth,

enriches from a rotation of crops and enhances its own fertility.

With this philosophical approach, Salam worked at Cambridge for fourteen to sixteen hours a day. He read widely and deeply, not only mathematics and increasingly physics, but also history; history of Islam and its culture, and history of India. He read all the scriptures of all major religions even reading Max Muller's Translations of Hindu scriptures of *Vedas* and Upanashidas-all available at the fine and comprehensive library of St. John's College where Salam spent most of his time in mathematics. He completed his three years' Tripos course in two and became a wrangler without much difficulty. In fact in his second year he was already attending the third year lectures in Quantum Mechanics and Relativity—subjects he was to specialize in later for research in theoretical physics. Wrangler is a Cambridge traditional term for a first-class mathematician.

According to Lord Hailsham, the difference between those who are admitted first class in their own field, and those who are not, lies very often in the fact that the "firsts" are able to formulate a coherent account, in lucid terms, of what they are trying to do or what they believe, whilst the others are not.

This is of course not always true but it describes Salam exceedingly well.

Salam, was and still is a slave to his work. He acquired, and has retained an almost unlimited capacity for absorbing information,–great powers of concentration, and meticulous habits of scholarship. Academically he is exceptionally gifted, and being intensely restless and competitive by nature, he made full use of his gifts at Cambridge. In the process he has surprisingly maintained good health. Probably a man does not work himself to death unless his work sets up conflicting emotions. Emotional stress is related to enthusiasm. The breaking point is reached when the tasks in hand become too numerous to be tackled with matching skill and success. Within the limits of even the longest possible working hours something needs to be neglected, and in the neglecting of the various somethings a man thinks himself not as efficient, competent and brilliant as he used to be. So an emotional conflict sets in. This leads to ill-health and finally a serious illness or, perhaps

even more tragically a languishing of mental vigour resulting in incompetence. This may sound irrelevant and incomprehensive to readers in the developing countries where only a selected few work at that pitch but for Salam this situation has never arisen. He had always maintained an incredible capacity for work. He has that secret to preserve the power of working continuously for sixteen hours a day, if need be. It is more than a simple stamina.

While Salam was finding a place in the new world of Cambridge, the British dissolved their Indian Empire in 1947 and the new Muslim Country, Pakistan, came in to existence.

This period from March 1947, of riots and killing in the Punjab, was to provide one of the bigget stresses for a sensitive man away from those he loved. There were riots in Multan, where his parents lived, and in Gurdaspur where his future wife lived. And the continuous trek of people presented a shocking spectacle across the border, destitute and defenceless Muslims attacked by murderous groups while crossing into Pakistan. For Salam in England, all this came in the news and he desperately wanted to return to join his family to share the privations of an independent nation. He was advised to stick to his work by all his well-wishers, his presence at home could not help, but after his Tripos in 1948, Salam felt a duty to return home and work among and serve his own people.

But before leaving for Pakistan he, however, received advice from two completely independent sources. One was from the head of the Ahmediyya Community who interpreted it as a cowardice on Salam's part to leave Cambridge by abandoning the third year scholarship that had already been awarded to him and advised him to stay.

The second piece of advice was offered by Fred Hoyle who told Salam to take a one year course in advanced physics in the Cavendish. Salam had told him his life's goal now as he saw it was to take up research in Theoretical Physics and follow where Dirac had left off. Hoyle said: "you must do experimental work before becoming a theoretician otherwise you will not be able to look an experimental physicist in the eye".

Salam had not formally studied for experimental physics after his F.Sc. examination and therefore hardly had done

any experimental work with his own hands. When Salam joined part II physics in his third year, he was no good in the laboratory. He would get bizarre results in his experiments and explain them by inventing a new theory. According to Salam: "For experimental work you need qualities I totally lack—patience and an ability to make instruments work. I knew I could not do it. Impossible, I just had not got the patience." But he got a "First" in Physics as all the examination work was not in the laboratory. On hearing the result, Salam's laboratory supervisor (now Sir Denys Wilkinson) warily commented: "how wrong one can be in judging one's students". Sir Denys knew Salam only as a (poor) experimenter!

Salam returned to Pakistan in 1949. The first person he met on return was Mian Afzal Hussain in Karachi who was now Chairman of the Pakistan Public Service Commission. Mian Sahib asked Salam if he wanted to join the Civil Service since the CSP examination was now being conducted. Salam said he was bitten by a different bug—he wanted nothing but a science career and could Mian Sahib help him get an extension of the Peasants' Scholarship. Mian Sahib—himself a distinguished botanist was delighted with Salam's choice of career and the scholarship was extended on Mian Sahib's recommendations. Salam in the same summer got married to his cousin, Amtul Hafeez Begum, the daughter of his uncle Ch. Ghulam Hussain. It was an arranged family marriage. The marriage brought further stability and contentment in his personal life. He now has three daughters and a son from this marriage.

But to pursue research he had to return to Cambridge. His scholarship was too meagre for him to support a wife in the UK and so, just after six weeks of marriage, he went back alone. Back at Cambridge Salam joined the Cavendish under Sam Devons to experiment on deutron-tritium scattering, but soon tired of the experiment he changed to theory. Prof. Kemmer became the supervisor for Salam's Ph. D. work. Right from the start Salam appeared to have been seeking for some field, some speciality, in which he would be able to gain, and hold the position of an unchallenged leader.

He found his way onto some problems in quantum electrodynamics, then a field of intense interest and rigorous investi-

gations. P.T. Matthews, now Vice Chancellor at Bath University, was at that time a Cambridge research student. Salam was told by his supervisor that "there were a few problems left in quantum electrodynamics but all of them had been solved by Matthews". So Salam went to Matthews and asked him if there were any crumbs left. At that time Matthews was leaving for Institute of Advanced Studies, Princeton to tackle an important problem regarding divergences in Meson Theory. While calculating the mass and charge of an electron, these divergent terms in the theory produced an infinite mass and an infinite electric charge. With great insight physicists like Julian Schwinger, Richard Feynman (both Nobel Laureates of 1965 for their fundamental work in quantum electrodynamics, with deep-ploughing consequences for the physics of elementary particles), and Freeman Dyson had indicated how the difficulty could be overcome, but the complete mathematical proof was lacking. Paul Matthews wanted to tackle this problem by going to Princeton where Dyson was working at that time. So Matthews told Salam to look into the problem to see if he could solve it before September (1950) while he (Matthews) took a vacation, otherwise Matthews would take the problem back to tackle it at Princeton. Salam solved the problem before the stipulated period was over and thereby made an important contribution to the renormalization in Meson Theory.

He solved the problem as he penetrated more deeply than others into its difficulties; in part by sheer strength of intellect, in part by reason of a deeply philosophical cast of mind, in part by normal courage and partly by invincible persistence and unflagging effort. It proved good for him to have lived under strict discipline, to have been down on the realities of existence by living on bare necessities. At this time he was also sufficiently confident of the powers of the intellectual tools he already possessed. This five months' effort was his Ph. D. work. It also earned him an international reputation of a very high order. By this success he had acquired the confidence and the enthusiasm to do any job, just as he had never before in his life gone into any challenge to lose. His vocation now was science and he had made up his mind to accept the comparative poverty which was its necessary adjunct. It also became clear to him, in this period, that a man of his temperament and faith, the sole

secret of getting through life with anything like contentment was to have full scope for the development of his faculties. Science alone seemed to him to afford this scope. Science is a conscientious human attempt to set in ordered pattern the truths of experiments and experience, and physics becomes an endeavour to arrange experimental facts in most economical and elegant order with the help of mathematical logic and its symbols. Experience taught him where his vocation really was; it was through enjoyment and not aversion that he discovered his fitness for the work the "accidents" put his way. To marry oneself to a job from any motive but love is as bad as marrying for money. And Salam loved his work in science When asked how did he solve one of the biggest problems in physics at that time, Salam said: "Well, I was helped in it by Freeman Dyson. He was the man responsible for the entire development. He had set out the Renormalization Programme and he had done it for all orders of electrodynamics, though not for the Meson Theory. Dyson happened to be in Britain at the time. So I rang and told him: 'You may be able to help me solve the problem that is worrying us—the central problem of the Meson Theory. May I come and see you?' Dyson said he was leaving for the U.S.A. the next day and asked me to go and see him right away. And that again was an accident that shaped my life. When I met Dyson and asked him for a solution, he replied: 'I have no solution. I have only a conjecture'. When I heard these words it was like the earth slipping from under my feet. For Dyson was like a semi-god to me and I had expected him to know all the answers. Nevertheless, he gave a highly illuminating exposition of the subject and that put me on the right track. Eventually I was able to prove that Dyson's conjecture was right. And my work got me a doctorate and an immediate Fellowship at Princeton".

For him Cambridge proved to be a thoroughly fruitful experience while his studies took a new measure of meaning. Research became exceptionally delightful and stimulating for him. In 1950 he was awarded the Smith's prize from Cambridge for the most outstanding predoctoral contribution to physics. This period also led Salam to develop a most productive collaboration with Matthews in England. This lasted for the next fifteen years of his life. Hardly had two people of so

different temperaments worked so closely for so long for the singular love of research.

Salam's thesis work was sent to Freeman Dyson at Princeton for assessment as he had already worked on this topic as mentioned earlier. Dyson also discussed the subject in detail by correspondence with Salam and told Robert Openheimer that Salam, in spite of being an Asian, is an exceptionally brilliant young man. So Princeton invited Salam to work at Princeton for a year in late 1950. During this period Salam saw Einstein closely at Princeton struggling intensely for the unification of gravitational and electromagnetic forces. As Salam had no provision for a scholarship for the third year to stay at Cambridge he was permitted, through a special dispensation, to go back to Pakistan and submit his thesis formally from there after the completion of three years as prescribed by the University rules. While leaving Cambridge he requested his Supervisor for a letter of recommendation indicating that he had worked satisfactorily during his Ph. D. period, and his supervisor replied: "I think you should give me a testimonial that you have worked with me". Salam formally submitted his thesis from Lahore in 1952 and got his Ph. D. from Cambridge for the work already completed in 1950.

Salam proved to be one of those rare striking cases, where a youngster by reason of researches carried out far from home, landed with one leap at the very forefront of his scientific field. Salam's proof in renormalization was based on the physical interpretation of the electron charge renormalization as follows: "an electron of a negative electrical charge is surrounded by a cloud of its virtual anti-particles, called positrons, which are exactly similar to electrons except that each positron has a positive electrical charge. Normally a positron cannot coexist with an electron but reacts with it to destroy itself and the electron—and this destruction results in the production of energetic radiation called gamma radiation. But a 'virtual positron' is considered to appear suddenly, in the neighbourhood of the electron, out of the vacuum, and before it can react with the electron it vanishes again, only to reappear in the next fraction of time, and so on, mindful of the Heisenberg principle of uncertainty which states that the product in the uncertainty in energy and the fraction of time during which

that uncertainty persists cannot exceed a certain constant value called Planck's constant.

This vanishing feat of the virtual positron gives it such a short life-time that it cannot be observed experimentally. The life-time for which it actually exists is sufficient, however, to maintain constantly a thick cloud of these positrons around each electron. This cloud of virtual positrons can never get sufficiently close to destroy the negative charge of the electron but they are close enough to reduce it. It is this reduced and very greatly diminished electrical charge of the electron which is traditionally given the value of minus one; otherwise the bare undiminished charge of the electron before it is reduced by the cloud of virtual positrons is assumed to be infinite. This type of concept was mathematically formulated by Salam in the renormalization of Meson Theory.

This concept of renormalization finds an analogy in a recent interpretation of the Sufistic view in Islam. A.Z. Faruqui in his illuminating essay on "Islam in the age of Physics" writes: "...the soul of man is encumbered by the trivial preoccupations of our worldly life which smothers and ultimately destroys our capacity for spiritual progress. By renouncing the world and by exercises of purification, the soul is able to shed its material burden and to move towards intimate knowledge of Allah. Ordinary believing Muslim accepts this mystical thesis with respectful incomprehension". He further adds that renormalization concept "would take the intellect as far as it can go in comprehension of the incomprehensible, if only the unreal (virtual) cloud of material preoccupations is removed from the soul of man, it can realise its infinite potentiality for knowledge of Allah". Probably Dr. Annemaoie Schimmel referred to this infinite potentiality for knowledge by saying: "when it is said that a sufi knows seven thousand meanings of an '*ayat*' (Quranic verse) of the Holy Book, it means he goes deeper and deeper into its meanings as Sufis do not cling to the letter of the law but probe into the spirit of the law—this produces tensions between the Sufis and the Fundamentalists."

When Salam joined Government College, Lahore as Head of the Mathematics Department of his college as well as that of the Punjab University in 1951, he realised that Lahore had no conception of the fact that in its higher range at the M.A.

Level, University teaching was closely to be coupled with research, as neither can be properly pursued without the other. The teacher is destined to become stale without at least some recourse to research, or some interaction with the researcher. The student, as he approaches the frontier of knowledge in his M.A. degree, must acquire at least a momementary view of what is happening at the frontier itself. This can at least help him grasp the significance of what he is learning as a student. All this was and is missing at Lahore. Higher education and research had (or have) no place in Pakistan.

The consequences of the neglect of the Universities seem too delicate for the leadership to see. The whole apparatus of Society has been inadequate to take up the strains of a viable society. Our universities have never been assigned the central position of the nation's intellectual activity. There had been a failure of faith in the principle that many of the political personalities in any rational society ought ideally to emerge from the University system. Universities in developing countries are not expected to produce the new knowledge and ideas, both in the humanities and the sciences. And without new knowledge, it is not realized that societies become static, sluggish and barren. Research is central to learning and learning is the soul of the modern civilization.

The dilemma of the political leadership in developing countries has been that when a second-rate human intellect is employed, not merely will the initial object of achieving first class results be lost, but it will continue to be thwarted; for the second-rate intellect will recruit and promote second rate and third rate material to strengthen, perpetrate and succeed it. It will, therefore, lack and lose the ability and desire to audit and correct its own activities so as to produce the planned results. History is full of instances where exceptionally gifted minds imbued with intellectual and moral integrity were superseded in the race for leadership by second-rate people assisted by second-rate patronage. This digression may find a relevance to what I narrate in the next few pages.

The Principal of his College which Salam joined after his research work at Cambridge and Princeton, observed in the first interview he gave to Salam: "We all want men of research here, but never forget we are looking for good and honest

teachers and good, honest college men. This college has proud traditions to up-hold" (what he meant was that many of its old students had succeeded in joining the Indian Civil Service and its analogue in Pakistan). "We must all help. Now for any spare time you may have after your teaching duties, I can offer you a choice of three extra-curricular duties. You can take a wardenship of the college hostel, or be the chief treasurer of the college accounts, or, if you like, take up presidentship of its Football Club."

Offer of a choice of three college jobs was a reward for the recognition of his research achievements for which Cambridge awarded him the Smith's prize and Princeton honoured him by inviting him to work there for a year. While offering this choice the college Principal had probably the mental picture of the mythical research scholar who according to all descriptions and conventions is eccentric, conceited, absent-minded, devoid of common sense, deficient in general knowledge, aloof and given to idiosyncrasies of dress and manners. A view of this nature, to a large extent, still persists in the developing countries. Research scientist is commonly thought to be a man apart from the main body of the citizens. The fact is that science is an aspect of life shared in varying degrees by all progressives. Scientists are merely those men whose destiny and distinction it has been to make a close and deep study of a certain aspect of this knowledge and to use this study as a basis for their living. So many scientists come from rather simple homes from which it is difficult to get into other profession that bring large financial rewards. Scientists also have a desire to win in a competition. The desire for security and for keeping one's family financially afloat is common to all men and applies to scientists just as to everyone else. But in developing countries, the only use of the scientists by the political leaders, is for window-dressing. The political leaders may in this respect be likened to enlightened individuals who maintain scientists as zoo animals in natural surroundings of the laboratory jungles.

Salam finds the situation very depressing. He says: "it is astonishing, miraculous, that, considering all the hazards that beset a poor society, any talent at all is saved for science. These hazards are first, poverty and poor schooling, second

Civil Service which skims off the very top of the country's intellect; and third the chancy nature of any opportunities for an extended apprenticeship for research—especially when for the most part the university systems remain weak, static and uninspired."

Salam found no good library in Lahore and could maintain no communication with research groups abroad. He felt isolated and isolation in theoretical physics, he considered, was death. As Salam looks back on this period of stay in Lahore, 1951-1954, he says that if at that time someone had said to him: "We shall give you the opportunity to travel every year to an active centre in Europe or the United States to work with your peers for three months of your vacation, would you then be happy to stay the remaining nine months at Lahore? I would have said yes".

Salam was intensely saddened by an incident that turned up in December 1951 when Professor Wolfgang Pauli, winner of the Nobel Prize in 1945 for the discovery of the Exclusion Principle, visited Tata Institute at Bombay. To enable him to meet Pauli and to attend his lectures a return ticket was sent to Salam by Dr. Bhahba—a fine gesture to acknowledge the high value of the work Salam had completed on renormalization. Salam, 25 years old, left for Bombay in all his eagerness to discuss his work with Pauli during his Christmas holidays. On his return, Salam was charge-sheeted by his College Principal as he should have asked for official leave even during the vacation if he was going ex-Pakistan. Finally his absence was regularised as 'leave-without-pay' through the good offices of the then Director of Education who was well-disposed towards Salam.

In the annual confidential report of Salam for 1951, the Principal recorded that "Salam is not fit for Government College Lahore. He may be excellent for research, but he is not a good College man". Salam could not occupy the College residence to which he was entitled and lived for the period 1951-1953 in a single room in the house of Professor Qazi M. Aslam while his family stayed in Multan which Salam used to visit on weekends. Salam genuinely feels sad for the tragic under-development of his people and his country. It is happy augury that an offer of visiting his peers for three months every

year never came his way because this may have consumed him. The consumptive system eventually turned him into a crusader.

Salam was not a case of brain-drain for research in Pakistan. He became a case of a double-gain for his contributions to British as well as European scientific efforts. At Lahore, he was fairly sterilised for research by the excessive teaching load, extra curricula activities and general approach of society towards research. The society did not seem to recognize how a creative mind was nurtured and trained. And Salam had, ever since, talked indignantly of the waste of talent owing to state neglect of research and science. He has always thought that science is as important for development of a country as the army is for its defence.

He spent three troubled years in Lahore before the professional and social frustration drove him back to England. He found the academic climate in Lahore chilly and unfavourable to learning as the students even felt no prompting for acquiring knowledge. They were only interested in passing examinations. Science and learning were ignored not only by the intellectual leaders of the new nation, but also by the brightest students. He simply felt intellectually lonely. He dabbled fruitlessly in cosmology though his essays in the theory of superconductors were the first to bring field theory in that discipline. But all in all he, again, paid a heavy price in time for being genetically attached to a poor country.

Another significant event that greatly affected Salam's life and may have tipped the scales against his wish to remain working full time in Pakistan is an event he has never spoken of in all his life. This was the anti-Ahmediyya agitation of 1953. These riots also produced the first Martial Law in the country. A politician who had woven his design to oust the then foreign minister of Pakistan, an Ahmedi Muslim by faith, aided and promoted a controversy that led to anti-Ahmediyya riots in the Punjab. Salam felt deeply hurt. It agitated his mind. He saw deaths and ruined homes caused by his own fellow Muslims and fellow-citizens out of sheer hatred fanned and provoked by religious divines and exploited by politicians. He was deeply moved and stunned with horror and rejection, and all the cruelty and sufferings which had gone on from

sectarian hatred. It intensified his anguished feelings when he was warned of a pending attack on his life in his own home. He hurriedly got together with his father, mother and brother who were then staying with him in Lahore, and secretly abandoned his house and sought protection in his old teacher's (Mr Abdul Hamid's) house. At the time I remember there were rumours in Islamia College that he had been killed by a mob. He felt a stab of pain on account of this ugly development. The wounds now have healed outwardly since he has never spoken of them but they must have left a scar on his sensitive mind.

Islam for me preaches tolerance in belief and mutual understanding among various denominations and religious groups. It is time we recognised the need for co-existence despite various differences in faiths and in opinions. Tolerance must replace antagonism. Fanaticism and orthodoxy must not lead to violence. *Ijtehad* (e.g. research) must promote, relate and explain modern knowledge in the context of the modern scientific and technological age. The Quran is the Book of GOD for man to seek guidance for all times. The meanings of the Book's verses are simple, deep, artistic, philosophical, scientific, socialistic, political, moral, judicious and more. The Quran contains all knowledge attained by human society and to be attained in the future. This brings in the dilemma of its comprehension by any human society at any one time. This dilemma reveals the limitation of the human mind to comprehend the infinite knowledge contained in the Quran. Another dimension of this dilemma is that the limit and nature of this comprehension may vary with time depending on the magnitude of the acquired knowledge as possessed by a certain society at a given time. And that is where *Ijtehad* (e.g. research) and tolerance come in for attempts to resolve these various dilemmas and to harmonize modern scientific knowledge with the teachings of the "Quran". And in these attempts mistakes made have to be tolerated as a man who makes no mistake usually does not endeavour to achieve anything.

In the past even a proper vocabulary was lacking to translate and comprehend correctly the verses of "THE QURAN" in the light of the latest scientific developments, and therefore, the exact meaning of certain verses could not possibly be fully grasped. It also implies that a thorough linguistic know-

ledge is not in itself sufficient to understand correctly the verses from THE QURAN. What is needed along with this is a highly diversified knowledge of sciences and humanities embracing many disciplines.

It is, therefore, with an open mind, clear conscience, complete tolerance and without unnecessary fear that one had to approach the correct interpretation of the verses of the Holy Book. To elaborate my point. I quote a specific example from Maurice Bucaille's book "*The Bible, The Quran and Science*". According to this book the Quran reveals the complex mechanism of human reproduction in verses 1 and 2 of *Sura* 96, Verse 5 of *Sura* 22, Verse 67 of *Sura* 40 and Verses 37-38 of *Sura* 75. The majority of translations of the referred verses according to him, describe man's formation from a "blood clot" or an adhesion. This translation is totally unacceptable to scientists of this specialized field in this age of developed science. To comprehend the correct meaning of these verses one has to acquire a knowledge of anatomy, physiology, embryology, obstetrics, etc. And this brings in the problem of choosing the right meaning and interpretation from the various meanings of the Arabic words.

In all the above verses an Arabic word, "*Alaq*" has been interpreted as blood clot which is one of its many meanings. Its other meaning is something which clings. This enlarged meaning of the word "*Aloq*", puts the Quranic interpretation of man's reproduction in harmony with modern scientific knowledge, as fully discussed by Bucaille in his book.

This was a digression from the main theme. Returning to my topic Salam with his wife and his child—now Dr. Aziza Rehman, a Ph. D. in Biochemistry—left Pakistan to take up a lectureship at Cambridge University in England in 1954. This was not an ordinary decision for him. At the height of the anti-Ahmediyya riots, in March 1953, Sir Rudolf Peierls, Professor of Theoretical Physics, had written to Salam to ask if he wished to return to the U.K. because of the riots. Peierls said he could perhaps arrange a Fellowship for him at short notice. Salam had then turned the offer down.

In July 1953 the offer was repeated; this time without his consent. Cambridge University proceeded to elect him to a

lecturership, left vacant by the departure of his teacher, N. Kemmer, who took up a chair in Edinburgh. Salam had never applied for this lecturership. Cambridge University asked him to make up his mind to accept this offer by 30 September 1953. Salam pondered and hesitated—he loved his country. He still hoped he could build up science in Pakistan, in spite of all the discouragements— scientific and personal—he had received. But in the end all advice he received, convinced him he must turn himself into an exile. He cabled on 30 September 1953 to Cambridge University that he would come. He joined in January 1954—a fateful decision for the man who, through that decision, was to win the first science Nobel Prize for Pakistan and for all the other Muslim countries.

Salam at Cambridge (1954-1956)

Abdus Salam was the first world Muslim and the first scientist from Indo-Pakistan subcontinent to be offered a position of a lecturer in the faculty of Cambridge University—the most prestigious and the second oldest University in England.

The type of faculty member the University looks for is to be a teacher, but first and foremost, he must be a scholar, in love with learning, with a gift and a passion for research, and an investigator who can critically enquire and publish—so Salam was offered the lecturership as he, despite his uncomfortable stay in the scientific desert of Lahore, succeeded to publish six high quality research papers in theoretical high energy physics.

From India, before him, the only scientists who worked at Cambridge, as research fellows, were Dr. Bhabha—a rich Parsee and a brilliant scientist who initiated and orbited successfully the development programme of Indian Atomic Energy Commission with the explicit help and encouragement of the then Indian Prime Minister, Pandit Jawarlal Nehru, and the famous Indian mathematician Ramanujan, who worked with G.H. Hardy at Trinity College, Cambridge.

There was also Chandrashekhar before Salam who did Tripos and a Ph. D. in physics from Cambridge but went to

the University of Chicago to teach physics there. The only person from India who held the position of a professorship before Salam and Chandrashekar in the U.K. was Radha Krishna who taught philosophy at Oxford—and later on was honoured to be the second President of India.

In spite of anti-Ahmadiyya riots of 1953, in spite of the shabby treatment at the Government College, Lahore, Salam loved his country deeply. He did not want to accept to be in exile when Cambridge University asked for Salam's services. In the end men like S. M. Sharif—then Secretary of Education at Lahore—sensing the great honour done by Cambridge University to a Pakistani, persuaded Salam to accept this offer.

According to the Punjab Government Notification No. 6075/2, dated 16th February 1954, Abdus Salam was permitted to take up his assignment on deputation at Cambridge as Lecturer with the following terms and conditions.

"The Governor of the Punjab is pleased to place the services of Dr. Abdus Salam, M.A. (Pb) B.A. (Cantab.) Ph. D. (Cantab.), Professor, Government College, Lahore, at the disposal of the University of Cambridge (England) for appointment as Stockes Lecturer in Mathematics for a period of three years or less (if he should return to Pakistan earlier) with effect from 1-1-1954.

Dr. Abdus Salam's appointment at Cambridge carries the following terms:

	Per annum
(a) Fellowship at St. John's College	£ 300
(2) Stipend for lecturer at the University	£ 450
(3) Allowances	£ 50
Total:	£ 800

During the period of his deputation, Dr. Abdus Salam will draw a special allowance of Rs. 180/- p.m. from the Punjab Government."

At Cambridge, the formal teaching load for Salam was three hours a week for undergraduates for the first two terms of the academic year and three hours lecturing graduate students, undertaking Ph. D. work for the third term. There was also an additional work of supervising the undergraduates who

come in batches of two to learn and discuss with a teacher. Salam had to spend at least six hours a week on this supervisory work. This made Salam rather unhappy as it took that time away from his concentration in research. He, however, led a quiet life, deeply absorbed in his research, and cut his leisure to a degree that amounted to a form of self-denial.

In its first year at Cambridge Salam taught the 'Dirac Course"—a comprehensive course in quantum mechanics, to the graduate class as Professor Dirac went on leave of absence away from Cambridge that year. The tradition in mathematics at Cambridge for undergraduates is that each subject is taught simultaneously in two separate class-rooms by two people and students are allowed to attend any lecture they fancy. Salam was assigned to teach 'Electricity and Magnetism'. He became so popular with the undergraduates that in the very first year about two-third of the total students started attending his lectures while the rest went to the class of the second teacher.

Though Salam was not the first to discover that the easiest way to capture and maintain the interest of students was to introduce and familiarize them to one's own problems, and to reveal one's own doubts about soft spots in accepted learning, this approach was the one Salam applied in his lectures. And this made him successful in attracting several first-rate research students at Cambridge—like Walter Gilbert who won the Nobel Prize for Chemistry 1980, J.C. Taylor, now Professor at Cambridge, J.C. Polkinghorne who was also a Professor at Cambridge till he resigned to take the Holy Orders, R. Shaw of Durham University and Riazuddin of Pakistan. As a teacher, Salam never talked down to his students; he has always believed that students should come up to his standard. His lectures are always clear, deliberate, never repetitive, but always logical.

During his period at Cambridge, Salam's achievements upward continued in the scientific research and his development as a human being moved on without interruption as a result of the rapid accretion of knowledge and experience. While he was indefatigable in his research work, he realised from the study of human history that an understanding of human problems is as important as excellence in the creative

knowledge of facts and laws applicable to theoretical physics—the field in which he made researches and initiated new lines of investigation.

At Cambridge, Salam, being a Fellow of St. John's College, was offered an apartment where he settled down with his wife and four year old daughter. Fellowship of a College at Cambridge entitles the fellow for free evening meals in Hall, a room in the College and a free funeral.

Trinity College, the best known College in Great Britain, also offered Salam a Fellowship but Salam turned it down on aesthetic grounds as the flower gardens of St. John's captivated him. For Salam the Trinity grounds were not as pleasing as those of St. John's. His rejection also created a record in the history of the Trinity College as no one before him had ever refused a fellowship of Trinity College.

With a vast intellectual and mathematical arsenal at his disposal, Salam got absorbed in research at Cambridge. In 1954, he published one paper as he had lost his creative momentum due to the unpleasant experiences in Pakistan. In 1955 he published five papers including one on "Propagators of quantized fields." In 1956, he published four papers, mainly on "generalized dispersion relations" where one could also calculate the back scattering amplitude in strong nuclear interactions.

During this period Salam also completed an important work on "parity-violation" which came into prominence when, in 1957, experiments, under the suggestion of Professors Yang and Lee who qualitatively showed by reviewing all the experimental data available that there existed no evidence to prove that parity is conserved in weak interactions. The experiment performed by Wu, *et al.*, explicitly showed that parity is violated in weak interactions.

However, Salam was already famous among the top world physicists by 1956, mainly for his high-quality work in renormalization and dispersion relations. He attended the first Rochester Conference in 1955 where fifty of the most selectively active physicists were gathered to discuss the latest trends in high energy physics. It was also in 1955 that Salam was asked to serve as a scientific secretary at the first Atoms for Peace Conference convened by the UN in Geneva, Switzerland.

Like many others, on that historic occasion, Salam was greatly impressed, and he fully sensed the strength of world science and its power to work wonders for the benefits of all countries. As events proved, these were merely the rumblings before an avalanche of further honours started.

In 1957, Salam quantum jumped two rungs of the ladder in about three years of lecturership at Cambridge to become a full professor, at the age of 31, at Imperial College, London—to hold the record of being the first Muslim to be elevated to a chair in an Anglo-Saxon Society since the Industrial Revolution! And it was after he received this honour, that his country began to grow conscious that in Salam it possessed a remarkable son.

The way it came about is in itself most interesting.

Professor Hans A. Bethe, a German-born American physicist came to Cambridge to spend one year in 1956. He won the Nobel Prize for Physics in 1967 "for his contributions to the theory of nuclear reactions, especially his discoveries concerning the energy production in stars". Professor Bethe met Professor Blackett, the first time at Cambridge, in the thirties when Blackett was working with the cloud chamber to determine the energy of the ionizing particles by determining their range in the cloud chamber. As Bethe had already worked out an approximate expression for the energy loss of charged particles, Blackett told Bethe to formulate quantitatively the energy loss of charged particles in complex atoms to help Blackett in his work in the cloud chamber.

Professor Blackett, Father of Operational Research, a benefactor and a friend of exile scientists in England, a Nobel Laureate of 1948, "for his development of the Wilson cloud chamber method, and his discoveries therewith in the fields of nuclear physics and cosmic radiation", was in 1956 the Chairman of the Physics Department at Imperial College. He was looking for a man for a chair in theoretical physics at his College. He came to Cambridge, met and asked Bethe to recommend some suitable names. Professor Bethe, knowing Salam's work in renormalization, proposed his name to Blackett. Professor Blackett immediately, without loss of any further time, walked to Salam's office, knocked, opened the

door, faced Salam and asked: "Do you want a chair?" Salam, astonished, said: "Yes Sir."

Blackett: "It is done."

Salam: "Thank you."

Then, of course, there was the formal interview when Professor Temple, an admirer of Astronomer Eddington, asked Salam the first and the last question about the quality of Eddington's book on Astronomy. Salam had a low opinion about it but knowing Professor Temple's respect for Eddington's work, he replied: "I had not read the book with the detachment of a neutral mind." Professor Temple smiled with the comment: "Young man, you should go to diplomatic service."

The interview ended and Salam was offered the prized chair in the Mathematics Department of Imperial College, London, which previous to him had been held by intellectual giants like Alfred North Whitehead who had collaborated with Bertrand Russell in writing Principia Mathematica. Salam thus penetrated the Muslim barrier to science after centuries of Muslim stagnation in face of the revolutionary progress of the Christian World.

Salam was most reluctant to leave Cambridge as he was admitted to the company of men whose disciplined minds were far more sophisticated than any he had ever encountered before. This made Salam to talk to Nevill F. Mott who was then the Cavendish Professor at Cambridge. Professor Mott's predecessors at Cavendish had been J.C. Maxwell, Lord Raleigh, J. J. Thomson, E. Rutherford and W.L. Bragg. Professor Mott was awarded the Nobel Prize for Physics in 1977 "for the fundamental theoretical investigations of the electronic structure of magnetic and disordered systems". This information I am providing for the reader to comprehend the nature and the level of the men Salam was rubbing his shoulders with; as a close and intimate rubbing of shoulders with such men is immensely stimulating and is liable to produce far-reaching brain-waves.

Salam told Professor Mott that he would not like to leave Cambridge except for the benefits for his research that he would derive as a Professor at Imperial College, particularly because of freedom from "supervising" which was time-con-

suming. Salam had by then a family of two daughters, the second born in 1955. Professor Mott agreed that Salam should not go to the "Blacksmith's College"—the name given to Imperial College of Science and Technology by the Cambridge academicians. The deal proposed to compensate Salam for giving up the onerous duties as supervisor was to offer him the additional duties of the editorship of the *Philosophical Magazine*—a prestigious journal of physics—the duties Professor Mott was himself carrying out at the time, with the monetary additional benefits of £100 per annum plus "any amount of sherry" Salam might like to consume. "Sherry" was a side-line of Taylor and Francis who published the "*Philosophical Magazine*" and so Professor Mott could feel free with dispensing with it.

This offer Salam was constrained to decline as sherry was of no value to him and the tasks as Editor of the *Philosophical Magazine*, though more pleasant, would be as equally time-consuming as "supervising". This took Salam to Imperial College as a Professor of theoretical physics on 1st January 1957 at a salary of £3,000 a year.

Professor Salam at Imperial College

No country is any good unless it has something to swagger about. Pakistan did not have anything in scholarship except an ancient Muslim heritage embodied in Iqbal—so Salam's elevation to professorship in UK helped to show a certain measure of the achievements of the new-born country. Salam recalls the visit to London in 1957 of Mian Iftikhar-ud-din, the well-known politician who then owned and managed the *Pakistan Times*. Mian Sahib simply could not believe that a Pakistani could hold a full chair at London University. He kept repeating in disbelief—"Is it really true?" In the end Mian Sahib got the *Pakistan Times* to commission a full page profile of Salam to introduce him to his countrymen.

Pakistani students studying in Britain drew sustenance from Salam's position in England. I personally had the first exciting experience of discussing advanced physics with Salam in my own native tongue in 1958 perceiving sensitively the feeling that science can be the shared heritage of all mankind and not the sole monopoly of the western civilization as it had been for the last so many centuries.

I then felt proud at the realisation that physics is not something that could only be expressed and discussed in English

زمیندار اخبار کا تراشہ

میٹریکولیشن میں پنجاب یونیورسٹی کا ریکارڈ توڑنیوالا

مسٹر عبدالسلام

PROFESSOR SALAM WITH PROFESSOR J. R. OPPENHEIMER

INSTITUT INTERNATIONAL DE PHYSIQUE SOLVAY

HUITIEME CONSEIL DE PHYSIQUE — BRUXELLES, 27 SEPTEMBRE - 2 OCTOBRE 1948

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I. PRIGOGINE I. GEHENIAU E. HENRIOT M. VANSTYVENDAEL.

PROFESSOR ABDUS SALAM RECEIVING AN HONORARY DEGREE OF D. Sc. AT ALIGARH ON 24TH JANUARY 1981.

alone. Salam's appointment to the chair in the United Kingdom raised the general morale of all Pakistani students in England. Salam had established beyond doubt that the student community of the developing countries could come up to the highest standards of academic achievements. Among the Pakistani students, this event also introduced an element of self-confidence which led to their better performance in English Universities.

At Imperial College Salam energized the place with a torrent of ideas. With his immense vitality and a striking personality, Imperial College became the outstanding centre in England and in Europe for work in high energy theoretical physics. And it started attracting active physicists from all parts of the world including the United States.

Salam possesses the faculty of recognizing and comprehending the new fertile lines of research and has been able to distil from them the fundamental ideas. It is my personal opinion that philosophically, nothing in physics, in the real sense of the word, is original. Even Heisenberg's revolutionary concept of the Uncertainty Principle that one cannot measure the energy of a particle without altering it has before it T.E. Eliot's quote: "that examination of history alters history", or Ezra Pound's declaration that: "the act of thinking alters the thought itself." However, the difference between physics and philosophy is that physics has to make the concepts, it employs, quantitative and testable in laboratory experiments. Only those concepts which pass the test of experiment survive even though other rival concepts may appear aesthetically appealing.

Salam pours out ideas in a continuous stream in discussions with his colleagues. Occasionally, Salam is right and then his triumphant "I told you so" might be irritating to anyone who recalled that 99 others, voiced with equal conviction, were turned out to be wrong. He has, however, poured out research papers at an astonishing rate.

During his first eight years at Imperial College (1957-64), Professor Salam published 50 research papers and turned out about 20 Ph. D. scientists in theoretical physics. The total research papers published by Professor Salam upto 1980 are over 200 which include 51 in *Physical Review*, 32 in *Nuovo*

Cimento, 27 in *Physics Letters*, 23 in *Nuclear Physics*, 6 in *Proceedings of Royal Society* and 4 in *Pakistan Journal of Science*.

So at Imperial College, Salam continued to strengthen his success with more work rather than getting relaxed with it as to him "happiness is not good for work". For him science has been the sinews of his intellectual culture, though he has exhibited wisdom in his common dealings, in disposing successfully the affairs of his family, in making fit provisions for it, in the education and settlement of his children and other vital concerns of human life, including being able to give as much as he can to helping others monetarily and otherwise. Through the detailed pattern of his life, he has richly demonstrated that only a sense of commitment and ambition can release a man's creative energies and trace out the imaginative solutions to human problems to enhance increased destiny.

Salam has attended some 100 international conferences, has travelled up, down and around the world to gather information and discuss ideas, has kept innumerable engagements with people influential in science and state and made sure that right contacts were available to pursue and promote suitable lines of progress.

His travels to international conferences had been intellectual expeditions in which he headed straight, without feeling any jet-lag for the conference to participate and explore issues in science, conferring with other scientists, on scientific and economic problems, learning to understand the cultural and political conditions in which they worked and using his travels as a further means of developing his own ideas. He has developed or inherited somewhere, the capacity for constant readjustment of mind, spirit and body to environment as well as situations requiring quick understanding and outflowing tact. While talking to Professor Qazi M. Aslam, ex-Principal, Government College, Lahore and in whose home Salam lived for eighteen months during 1951-1953, I was told that, "Salam worked very hard but never gave the impression of working hard. Whenever one entered his room, one would find Salam working at his table. But he would immediately stand up to converse with you with complete ease and delight until one begged for leave. And after leaving his room, if one

cared to peep back, one would find Salam back at his table working as if nothing had disturbed him."

In 1957 experiments in the United States confirmed that parity is not conserved in weak nuclear forces as phenomenologically predicated by Professor C.N. Yang and Professor T.D. Lee. This was the year when the Russians first succeeded in orbiting their Sputnik around the world.

The symmetry involved in the law of conservation of parity is merely to say that if a physical process occurs, its image in a mirror is also a possible analogue. It means that the parity principle is an embodiment of the reflection symmetry in nature.

The experimental implication of the parity concept was that a beam of polarized particles (with spins aligned in a particular way) decaying through the weak nuclear force (also called weak interaction) would emit equal number of particles along its left-right directions if the parity is conserved. This was experimentally found to be incorrect which led Professors Yang and Lee to win the Nobel Prize for 1957.

The actual history of the development of the parity-violation concept is most interesting as in the words of Professor Abdus Salam:

"I heard at the Seattle Conference, Professor Yang expound his and Professor Lee's ideas on the possibility of the hitherto sacred principle, left-right symmetry, being violated in the realm of the weak nuclear force. Lee and Yang had been led to consider abandoning left-right symmetry for weak nuclear interaction as a possible resolution of the ($\mathcal{J}$ - Q) puzzle. I remember travelling back to London on an American Air Force (MATS) transport flight. Although I had been granted, for that night, the status of a Brigadier or a Field Marshal—I don't quite remember which—the plane was very uncomfortable, full of crying service men's children—that is, the children were crying, not the service men. I could not sleep. I kept reflecting on why Nature should violate left-right symmetry in weak interaction. Now the hall-mark of most weak interactions was the involvement in radioactivity phenomena of Pauli's neutrino. While crossing over the Atlantic, came back to me a deeply perceptive question about the neutrino which Professor Rudolf Peierls had asked

when he was examining me for a Ph. D. a few years before. Peierls' question was: "The photon mass is zero because of Maxwell's principle of a gauge symmetry for electromagnetism; tell me, why is the neutrino mass zero?". I had then felt somewhat uncomfortable at Peierls, asking for a Ph. D. viva, a question of which he himself said he did not know the answer. But during that comfortless night the answer came. The analogue for the neutrino of the gauge symmetry for the photon existed; it had to do with the masslessness of the neutrino, with symmetry under the γ_5— transformation (later christened "Chiral symmetry"). The existence of this symmetry for the massless neutrino must imply a combination $(1+\gamma_5)$ or $(1-\gamma_5)$ for the neutrino interactions. Nature had the choice of an aesthetically satisfying but a left-right symmetry violating theory, with a neutrino which travels exactly with the velocity of light; or alternatively a theory where left-right symmetry is preserved, but the neutrino has a tiny mass—some ten thousand times smaller than the mass of the electron. It appeared at that time clear to me what choice Nature must have made. Surely, left-right symmetry must be sacrificed in all neutrino interactions. I got off the plane the next morning, naturally very elated. I rushed to the Cavendish, worked out the Michel parameter and a few other consequences of γ_5 symmetry, rushed out again, got on to a train to Birmingham where Peierls lived. To Peierls I presented my idea; he had asked the original question; could he approve of the answer? Peierls' reply was kind but firm. He said: "I do not believe left-right symmetry is violated in weak nuclear forces at all. I would not touch such ideas with a pair of tongs." Thus rebuffed in Birmingham, like Zuleika Dobson, I wondered where I could go next and the obvious place was CERN in Geneva, with Pauli—the father of the neutrino—nearby in Zurich. At that time, CERN lived in a wooden hut just outside Geneva airport. Besides my friends, Prentki and d'Espagnat, the hut contained a gas ring on which was cooked the stable diet of CERN—entrecote a la creme. The hut also contained Professor Villars of MIT, who was visiting Pauli the same day in Zurich. I gave him my paper.

He returned the next day with a message from the Oracle; "Give my regards to my friend Salam and tell him to think of something better." This was discouraging, but I was compensated by Pauli's excessive kindness a few months later, when Mrs. Wu's, Lederman's and Telegdi's experiments were announced showing that left-right symmetry was indeed violated and ideas similar to mine about chiral symmetry were expressed independently by Landau and Lee and Yang. I received Pauli's first somewhat apologetic letter on 24 January 1957."

This is the history of parity violation concept and Salam's anticipation of the crucial role of the two-component neutrino in parity violation in weak interactions.

The *London Times* on the day of the announcement of the 1957 Nobel Prize to Professors Yang and Lee raised the question whether their Prize may have been shared with Salam. Yang and Lee had the priority in questioning parity principle, Salam had the priority in formulating the two-component theory—the theory which replaced the fallen parity symmetry principle. The Nobel Award emphasised the value of the initial doubts about the parity principle which Yang and Lee expressed. However, one may imagine that the 1956 work of Salam may have counted towards his Nobel Award in 1979.

One thing which is clear from the extract above in his Nobel Lecture was Salam's unbounding admiration for Pauli. Pauli was a physicist of the great generation and class of Heisenberg and Dirac. He had worked with Neils Bohr and Heisenberg to develop quantum mechanics against the biting criticism of Einstein and who pronounced at the young age of 19 that Einstein's attempts to unify gravitational and electromagnetic forces would not succeed because of the lack of a physical idea in them.

It would be, however, interesting to record Werner Heisenberg's opinion about Pauli which he expressed when he was invited by Salam to Trieste in 1968 to reflect on his experiences of his life of physics.

Professor Heisenberg remarked: "If you try to solve a problem by rather dirty mathematics, as I have mostly done, then you are forced always to think of the experimental situation; and whatever formulae you write down, you try to compare

the formulae with reality and thereby, somehow, you get closer to reality than by looking for the rigorous methods. Pauli's whole character was different from mine. He was much more critical and he tried to do two things at once while I would think that this is really too difficult even for the best physicist. He tried first of all to be inspired by the experiments and to see in a kind of intuitive way how things are connected, and at the same time, he tried to rationalize his intuitions and to find a rigorous mathematical scheme so that he really could prove every-thing which he said. Now, this is, I think, simply too much, and therefore Pauli has through his whole life published much less than he could have published if he had abandoned one of these two postulates."

Salam also tried to do two things at once—one was to formulate a theory to explain the τ—θ puzzle and the other was to win over to his point of view two of the most prestigious physicists of the world, Pauli and Peierls—the physicists who were emotionally committed to a highly developed common-sense assumption. Although in the end he published his work in spite of their negative advice, there was delay in his publication and recognition of his brilliant contribution of 1956-57.

There might be more than two things Salam might have thought of doing at the same time. Once Sir Zafrullah Khan advised Salam to take the dual nationality of Pakistan and Great Britain, but Salam resisted as he wanted to be only a Pakistani citizen when an honour like the Nobel Prize comes his way and did not want to share with another country. In my personal opinion, probably he also subconsciously aimed not to share the Nobel Prize with any other physicist—an indication one gets from his limited range of collaboration upto 1964.

In all fairness, Salam's communication to Pauli was an act of rebellion against the established ideas of Pauli—as Pauli was the champion of parity conservation and Salam, though he had been acclaimed and respected, was still young.

With the non-conservation of parity in weak interaction established, the idea of a universal Fermi interaction in weak nuclear forces was put forward in literature in 1958 by Sudarshan and Marshak, Gell-Mann and Feynman, and Sukurai. Accompanying with the universal Fermi interaction

was the result that weak interactions are to be mediated, like electromagnetic and strong nuclear forces where γ and π-mesons are the mediating particles by particles, called intermediate vector bosons, of spin one. This formulation was published in the literature by Professors Yang and Lee among others. But Salam had these ideas even earlier. He describes how he sent two notes to Pauli concerning the universal Fermi interaction and intermediate vector bosons in early 1957. Pauli wrote back on 30th January 1957, then on 18 February and later on 11, 12 and 13 March 1957 as:

"I am reading (along the shores of Lake Zurich) in bright sunshine quietly your paper....". "I am very much startled on the title of your paper 'Universal Fermi Interaction'. For quite a while I have for myself the rule if a theoretician says universal, it just means pure nonsense. This holds particularly in connection with the Fermi interaction, but otherwise too, and now you too, Brutus, my son, come with this word....."

Salam writes: "I must admit I was taken aback by Pauli's fierce prejudice against universalism—against what we would today call unification of basic forces—but I did not take this too seriously. I felt this was a legacy of the exasperation which Pauli had always felt at Einstein's somewhat formalistic attempts at unifying gravity with electromagnetism—forces which in Pauli's phrase "cannot be joined—for God hath rent them asunder." But Pauli was absolutely right in accusing me of darkness about the problem of the masses of the Yang-Mills fields; one could not obtain a mass without wantonly destroying the gauge symmetry one had started with."

Knowing that a complete monopoly of folly does not lie with the uninformed alone, T. H. Huxley, in the late nineteenth century, observed that, as a general pattern, new ideas face four stages of public opinion. It would be interesting to recapitulate the following four stages for comprehending the situation which confronted the world of Physics at that time.

(1) The novelty is absurd and subversive of religion and morality—the propounder both a fool and a knave.

(2) (Twenty years later). The novelty is absolute truth and will yield a full and satisfactory explanation of things

in general—the propounder a man of sublime genius and perfect virtue.

(3) (Forty years later). The novelty wouldn't explain things in general after all and therefore is a wretched failure. The propounder a very ordinary person advertised by a clique. And

(4) (A century later). The novelty is a mixture of truth and error. Explains as much as could reasonably be expected. The propounder worthy of all honour in spite of his share of human frailties, as one who has added to the permanent possessions of science.

Because of his work, especially in weak interactions, Professor Salam, at 33, was elected a Fellow of the Royal Society, the most exclusive scientific body in the world. Salam was the first Pakistani and the first Muslim to achieve that distinction. Pakistan could then at least boast of an F.R.S. Later on Dr. Salim-uz-Zaman Siddiqui was the second Pakistani to win this honour in chemistry at a far maturer age.

By 1959, experimentalists had discovered scores of elementary particles. Then the theoreticians started asking: "Could the bewildering variety of particles be elementary?" Or was it as Salam asked, that "some are more elementary than others." This led to a classification into a few families of particles enabling them to say that particles of similar properties belong to one family. For predicting the size of a family they had to think of symmetry principles. The breakthrough began in 1960 when Yoshio Ohnuki of Nazoy, a University in Japan introduced the idea of "unitary symmetry" that might exist among "elementary particles". It started with the notion that most particles are composite particles made up of three fundamental particles which are themselves related to one another—proton, neutron and lemda (Λ^0).

Salam was the first non-Japanese physicist, himself an oriental mind, to accept this idea. This made Imperial College the centre of development of unitary symmetry. Salam and John Ward, a visiting scientist to Imperial College, used this idea in April 1961 to predict an eight-fold family of new meson particles of spin one which were duly discovered experimentally some six months later. At the same time, a research student working with Salam for a Ph. D., Yuval

Ne'eman from Israel, on Salam's suggestion (as acknowledged in his Ph. D. thesis), explored unitary symmetry further and went on to show that the baryons, the chief heavy particles including proton, neutron, etc., also formed an eight-fold family. This was first projected as a joint work but Salam with his characteristic generosity in such matters, asked his student to publish in his own name.

Independently, Gell-Mann of California Institute of Technology, came to the same conclusion. He used the symmetry concept to predict a very strange particle as a member of the eight-fold family—the omega minus—and when that, too, got detected in 1964, the unitary ideas were firmly established. (Murray Gell-Mann was awarded the Nobel Prize in 1969 "for his contributions and discoveries concerning the classification of elementary particles and their interactions.")

By 1964 Salam had already acquired the reputation of an Oracle—the only Pakistani among the scientific giants of the world.

His work on parity violation was first formally recognized by his own Cambridge University where he completed that work and which honoured him by awarding him the Hopkin's Prize for the best work in physics done by any Cambridge man during 1957 and the Adams Prize in 1958. In 1961 Salam became the first recipient of the Maxwell Medal, an Award of the Physical Society—the largest scientific society in UK.

In 1964, Salam also won the Hughes Medal of the Royal Society—probably the most exclusive, the most prestigious and the oldest scientific society in the world. Here I reproduce an extract from *Nature*—an outstanding British scientific journal—published on the occasion, 19 December 1964, when the President and Council of the Royal Society awarded him the Hughes Medal in recognition of his distinguished contribution to quantum mechanics and the theory of fundamental particles:

"Hughes Medal: Professor A. Salam, F.R.S.

There are very few physicists in the world who have maintained such a constant and fertile flow of brilliant ideas as Abdus Salam has achieved during the past thirteen years. His Ph. D. thesis, published in 1951, contained fundamental work in quantum electrodynamics (renormalization theory) which

had already gained for him an international reputation of a very high order. On two subsequent occasions, he has made contributions to the theory of elementary particles which are in the absolutely highest class.

In 1957, Salam proposed a deep and intimate connection between the zero rest mass of the neutrino and the parity non-conserving effects in weak interactions. This theory makes a large number of very specific predictions about neutrino properties, and of the way in which parity is violated in neutrino interactions, all of which have since been confirmed by experiments. In 1961, Salam, in collaboration with J.C. Ward, proposed that the strong interactions of elementary particles should satisfy unitary symmetry.

This implies that the particles and resonances should appear in supermultiplets of the same spin and parity, and well-defined isotopic properties. In particular, Salam and Ward predicted an octet of spin one mesons, playing an analogous part in strong interactions (e.g. strong nuclear forces) to the photon in electrodynamics.

All these mesons have since been found, and the general ideas of the theory recently confirmed by the spectacular discovery of Ω^- (omega minus).

These two pieces of work are both contributions to the basic laws of physics. They are not isolated achievements, but the high points in more than ten years of prolific and sustained performance. During this period, Salam has published about a hundred papers and maintained his position at the fore of this rapidly advancing frontier of the fundamentals of the subject."

Professor Salam's work on parity violation and in symmetry properties of elementary particles obtained recognition from the scientific community of Sweden by electing Salam a Fellow of the Royal Swedish Academy of Sciences in 1970. Salam received a telegram from the President and Secretary of the USSR Academy of Sciences at its Annual Session in March 1971 saying: "The General Assembly of the USSR Academy of Sciences at its Annual Session on March three, 1971, elected you Foreign Member of the Academy. On behalf of the General Assembly we cordially congratulate you and wish you good health and every success in your creative work."

Immediately thereafter, the scientists of the second super-power honoured Salam when the Secretary of the American Academy of Arts and Sciences wrote on 12 May 1971:

"In this envelope is a formal notification of election as a Foreign Honorary Member of the American Academy of Arts and Sciences. On behalf of the Council, I would like to congratulate you on your election and welcome you to membership.

The Academy's two thousand Fellows elect a small number of Foreign Honorary Members each year from citizens of foreign countries who are eminent for their discoveries or other attainments. . . ."

The University of Miami honoured Salam as a recipient of the J. Robert Oppenheimer Memorial Prize awarded annually since 1969 by the University of Miami Center for Theoretical Studies.

The 12-member Scientific Council of the University of Miami chose Professor Salam according to its news bureau, "in recognition of his contributions in quantum electrodynamics, and in elementary particles physics, especially the two-component neutrino theory of parity violation in weak interactions, and in symmetry properties of elementary particles."

The Scientific Council was composed of six University of Miami representatives and the following national representatives: Professor Robert Mulliken, University of Chicago; Dr. Gerald Edelman, Rockefeller University; Dr. Maurice Goldhaber, Brookhaven National Laboratory; Professor Lars Onsager, Yale University; Professor Julian Schwinger, Harvard University, and Professor Edward Teller, University of California at Livermore.

In 1964, Salam was appointed Director, International Centre for Theoretical Physics, Trieste in Italy. In 1960 as a delegate from Pakistan, Salam proposed in the General Conference of the IAEA to set up such a centre to resolve the problem of isolation of the active physicists in the developing countries.

Salam has directed, with inspired devotion the work at the school for which he has proved himself singularly well suited by the unique combination of his personality, his broad and deep scientific interest, his perceptive scholarship, the width of his learning as testified by the immense variety of various topics—scholarly, economic, political and religious—on which

he has written with ease and authority, and his knowledge of the men from developed as well as developing countries. Through his school at Trieste, Salam has, with smoothness and artistic colours, established his leadership in the scientific world—as leadership is essentially an intuition about human relations and an application of the principles of friendship into the impersonal fields of society and human life. As a true leader Salam has been as sensitive and rational to the methods of action by which his working colleagues are selected at the school as to their conditions of work. Globally he has become a towering personality by his own research work in physics, his influence as a teacher, his pioneering activities at Imperial College, the rapid growth of the Trieste school as a leading centre of theoretical physics and his singular efforts to promote a more common understanding of science in developing countries.

As Salam conceived the Trieste Centre as a place where men from all countries could work alongside some of the most distinguished minds of physics, he along with Sigvard Eklund, the then Director General of IAEA and Henry De Wolf Smyth, USA Ambassador to the IAEA, was awarded the Atoms for Peace Prize in 1968. The citation at the occasion read as follows:

> "By your acceptance of demanding administrative responsibility, you have helped to direct and focus the thoughts and efforts of people and nations. By your active and dedicated participation in international conferences, councils and agencies, you have given us leadership that knows no narrow boundaries of mind or geography. By your suggestions and proposals for greater cooperative efforts and by your willingness to work for their achievement, you have brought closer that day when the beneficent potentialities of the atom will be part of the life of every man.
>
> By the amplitude of your public spirit and your civil courage, you have earned a position of trust in your country and a place of confidence in the international community. By your radiant and altruistic careers, you have exemplified the bright ideals of science. May this medal symbolizing the Atoms for Peace Award signify to all men the importance of your contributions towards the use of atomic energy for the benefit of mankind."

So by 1968 Salam got accepted as a genius of the developing world through his unswerving devotion to a cause, inexhaustible energy for work, his mature understanding of the ways of men in science and in politics and his rare capacity as an organizer and an executive coupled with his genial nature.

But why this centre could not be set up in Pakistan will be discussed in the next chapter.

Now coming back to physics, the situation in elementary particle physics in 1964 was that, with the success of the symmetry concepts, the theorists were left with a set of well defined families of particles without any parenthood—no fundamental particles which could give rise to well-behaved families of particles.

It was in 1964 that G. Zweig and M. Gell-Mann first predicted independently three quarks called 'up', 'down' and 'strange' (u, d and s). These particles were prophesied to have not only the exotic number of fractional charge (*see* Table 1) but also fractional baryon number.

Quaih type	up (u)	Down (d)	Charm (c)	Strange (s)	Bottom (b)
Charge (electric)	$\frac{2}{3}$	$-\frac{1}{3}$	$\frac{2}{3}$	—/3	$-\frac{1}{3}$
Strangeness	0	0	?	1	0
Baryon Number	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$

Baryon number plus one is assigned to all baryons....like protons and neutrons. It is a quantity observed to be strictly conserved in all reactions, leading to the apparently absolute stability of the lightest baryon—the proton.

The baryons are considered to be formed from three quarks and the mesons from quark-anti-quark pairs; simple examples are neutron (udd), proton (uud) and π—meson ($\bar{u}$d) where $\bar{u}$ is the anti-up quark. The quark proposal was the culmination of a successful attempt to explain the numerous states (more than 200) of baryons and mesons (called hadrons) as three quarks could build all the known baryons and mesons. The only difficulty encountered at present is that free quarks have not been detected so far—their existence is only inferred from indirect predictions made by this theory.

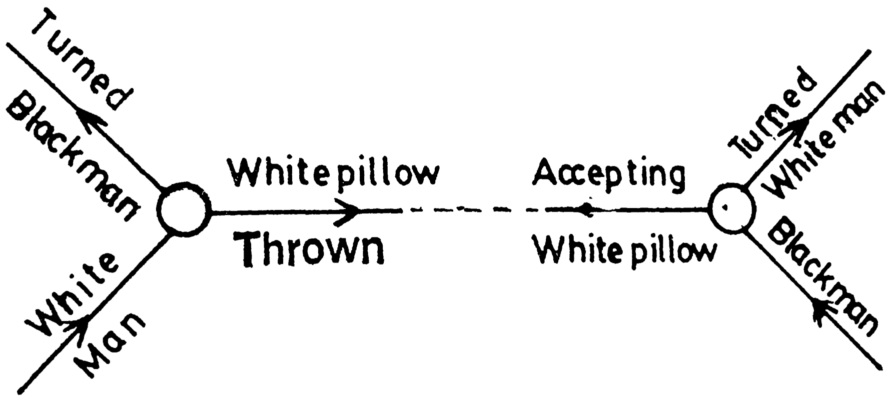
There is another family of particles called leptons. This consists of electrons, heavy electrons (called mu-mesons) and neutrinos. There is no explanation for the heavy mass of the mu-meson—why it is different from electron except that elec-

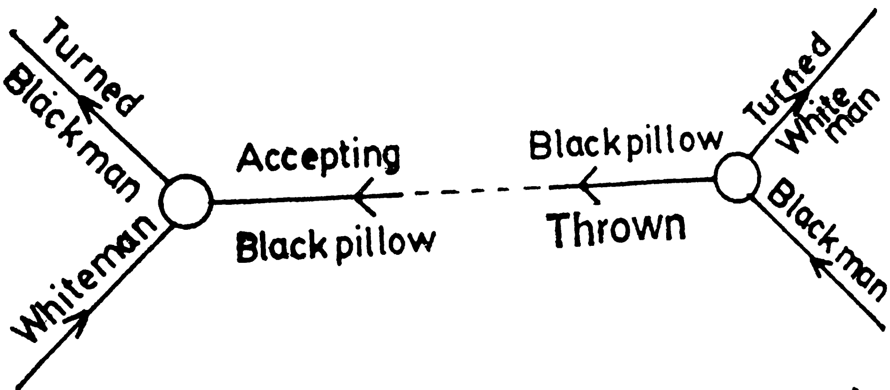
tron and *mu*-meson are found to be associated, so far, with different neutrinos—the difference in the nature of the two neutrinos is again unknown.

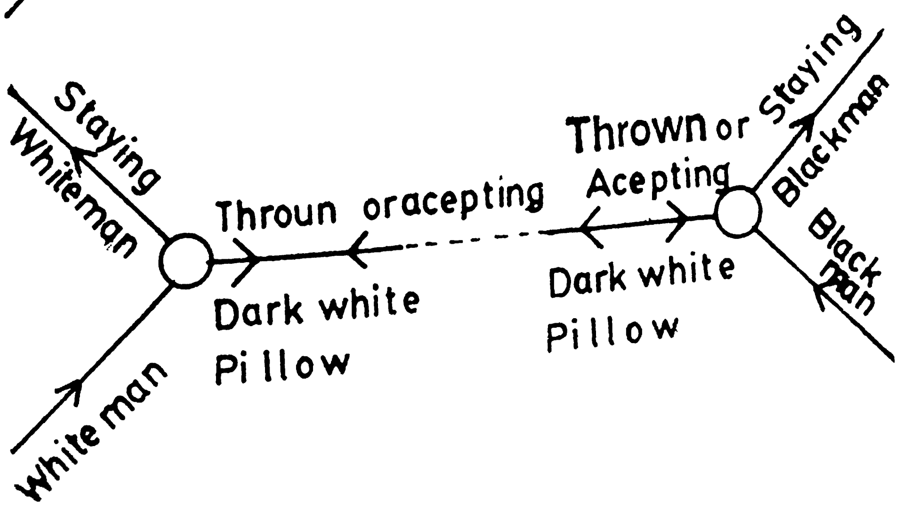
According to the present view, the quarks and leptons form the fundamental constituents of matter and they experience the same four forces that exist in the Universe except that leptons do not feel strong nuclear force. The four forces are: the strong nuclear force which is responsible for the nuclear stability of an atom, the electromagnetic force that acts between any two charged particles, the weak nuclear force which produces radioactivity and the gravitational force of attraction between any two masses of particles. The ratios of the strengths of these four forces are, respectively, $1:10^{-2}:10^{-5}:10^{-39}$. These four fundamental forces of nature have seemed for some time quite different from one another. Despite their different effective strengths, the strong nuclear force is effective only within sub-nuclear distances and therefore confines the nuutrons and protons within the nucleus on the one hand and makes the sun and the stars shine on the other. The electromagnetic force is long-range and causes all chemical reactions. It binds the electrons with the nucleus, atoms with molecules and atoms with crystals, molecules with micro molecules and connecting electricity with magnetism gives rise to the generation of electrical power. The weak nuclear force is short range, like the strong nuclear force, and governs more weird processes like the automatic breaking up of elementary particles as well as the radioactive elements. The gravitational force, like the electromagnetic force, is again long range, extending upto and beyond the remotest stars and galaxies, makes a man feel his weight, gives rise to ocean tides and keeps the planets moving in their orbits around the run. These widely disparate properties of the four basic forces have not deterred the mathematico-philosophical scientists from seeking a common cause for them all. Einstein, for example, devoted much of the last part of his life to the search for a unified equation of gravitational and electromagnetic forces. While no one has as yet been able to achieve success in this objective, Salam has succeeded—at least there seems to be a general concensus at present, in unifying mathematically the weak nuclear force with electromagnetism.

Two children playing with a pillow, by throwing or snatching the pillow, develop a force of repulsion or attraction as a consequence of momentum conservation principle. This is the fundamental concept by which all the four forces are being explained—qualitatively and quantitatively. Let me elaborate this principle. Consider a white man and a black man playing the pillow-game with three magic pillows, a white, a black and a dark-white.

The white man throwing a white pillow or accepting a black one changes his colour to black and his direction of motion to compensate for the momentum of the pillow. Analogously







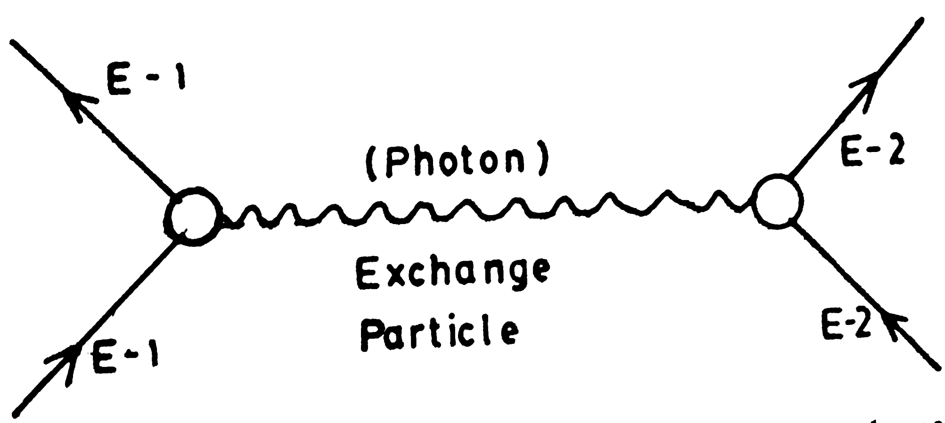
the black man throwing a black pillow or accepting the white one becomes a white man. Diagraphically it is represented as shown and are called Feynman Diagrams:
The white or the black man throwing or accepting the dark-white pillow does not change his color but changes its direction of motion only.

The conservation of momentum here means that a person moving in a certain direction (↗) when throws out a certain mass of a certain momentum (→) must change its own direction of motion (↖↗) such that the vector sum of his own final momentum (↖) and the momentum of the mass thrown (→) must equal the initial momentum (↗) of the person.

Enrico Fermi, the father of nuclear reactor and Nobel Laureate of 1938 "for his demonstrations of the existence of new radioactive elements produced by neutron irradiation, and for his related discovery of nuclear reactions brought about by slow neutrons", used the above mentioned pillow analogy to interpret the electromagnetic force between two electrons as mediated by exchange of photons.

Fermi replaced the whiteman by an electron and the black-man by another electron and these two electrons played the game with the exchange of a dark white pillow he named a photon.

Diagrammatically it is then represented as:



The photon is a packet of energy of zero mass, zero charge and spin one. It is also called a vector boson. In the mathematical theory of electromagnetic interaction, the electromagnetic force between the two electrons has associated with it the electric current. This current is coupled to its exchange

$(E-1 = e^{-}_{1}, E-2 = e^{-}_{2})$

particle, the photon, with the strength of electric charge e. This current is called neutral current as the exchange photon (darkwhite pillow) carries no colour or charge with it.

Hideki Yukawa, Nobel Laureate of 1949 for his prediction of the existence of three particles, called mesons (π^+, π^- and π^0), on the basis of theoretical work on nuclear forces, used this photon analogy to interpret the strong nuclear force between two protons or two neutrons or a proton and a neutron.

Yukawa, in the pillow game, replaced the whiteman with a proton, the blackman with a neutron and the three magic pillows with a particle of positive electric charge (π^+), a particle of negative electric charge (π^-) and a particle of zero electric charge (π^0).

This is illustrated in the figures 2-a and 2-b where at junction 1 in figure 2-a, proton throws away π^+ and turns into a neutron while at junction 2 the neutron absorbs π^+ and becomes a proton. In figure 2-b, the neutron throws out a π^- at junction 2 and turns into a proton (total charge to be conserved) and at vertex 1, the proton absorbs a π^- and converts into a neutron.

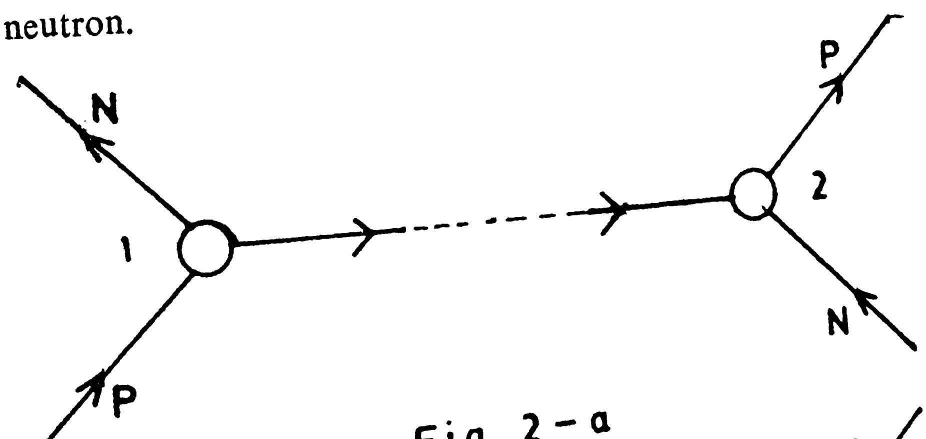


Fig. 2-a

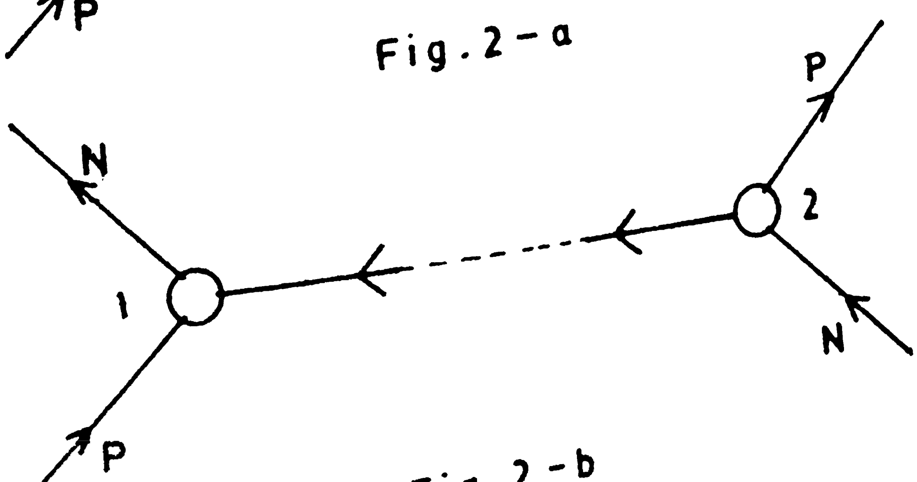


Fig. 2-b

A $\pi^{\pm}$ meson possesses a mass of about 150 MeV (an MeV is a unit of energy in particle physics), zero spin and electric charge plus, minus or zero.

In strong nuclear and electromagnetic interaction, the parity a left-right symmetry concept, is known to be conserved. Yukawa had to postulate these heavy π −mesons to explain the nature of short-range nuclear force—the force that exists only at a distance equal or smaller than 10^{-13}cm.

In exactly the same way, the weak nuclear force could not be considered to be mediated by an analogue of the photon or the π −meson exchange as the nature of this weak interaction looked to be more complicated than that of strong nuclear force or the electromagnetic interaction. Firstly the parity was known to be violated in weak interactions. Secondly, as proton can interact with another proton through the exchange of π^0— a neutral charge meson, in weak nuclear force no such interaction was found experimentally—like a neutrino scattering off a proton.

However, the weak nuclear force has a vector nature—vector minus axial vector form of interaction. This made it natural to seek a theoretical framework, a gauge theory, to describe it like the electromagnetic interaction which is gauge invariant. But there seemed to be at least two fundamental obstacles.

The one concerned the known form of the weak interaction which involves a change of charge by the participants, requiring the mediating particle to carry electric charge as neutron decaying into a proton, an electron and an antineutrino. In contrast, the electromagnetic exchange particle, the photon, is neutral and seemed to have no counterpart in the weak interaction. The second obstacle was that where a photon was a massless particle, the exchange particles in weak interaction have to be very massive to justify the short-range character of the weak nuclear force.

Symmetry principle has become a physicist's heuristic guide to discoveries regarding the laws of nature. As popular audiences cannot be expected to comprehend much above the level of superficiality so I limit myself in describing briefly the outlines of Salam's work on unification with a purpose to develop enthusiasm among young bright students of science—where the general reader may skip over the next few pages to avoid the depression of incomprehension.

Symmetries are of two kinds—global and local. Global symmetry, a geometrical concept, refers to a group of operations or motions in space such as translations, reflections or rotations which leave the form of an object unchanged or invariant. By extending the concept of these symmetries to space and time the mathematicians are working to understand and unify the manifold aspects of the universe as it has been, generally, accepted to apply these symmetries to more abstract entities of mathematical forms than the geometrical forms. In all these extensions, the basic idea of invariance or immutability, under a group of well-defined operations, remains exactly valid as in the invariance of a spherical configuration under any reflection or rotation around the sphere's centre or its central axis. For example, the four Maxwell's equations describing the electrical phenomenons remain invariant, no matter which system of coordinates is assigned to measure the electrical events. This invariance of Maxwell's equations is the result of space-time symmetry contained in Einstein's special theory of relativity which states that all laws of physics keep the same form in any two coordinate systems—systems used as a reference to measure the location of any event—provided the coordinate systems have a uniform or a constant relative velocity. Such an example of global symmetry is called Poincare invariance.

The other kind of symmetry is called local symmetry. Local symmetries are more revealing as they are obtained by an infinite set of operations carried out independently and individually. And the much stronger constraint of local Poincare invariance is established by requiring the laws of physics to retain the same form when the coordinates are transformed through local symmetry and not through one shot operation of global symmetry. This change is equivalent to allowing the two coordinate systems to have an accelerated relative velocity.

It would seem that observers in these accelerated coordinate systems would not derive the same laws of physics as an observer in an accelerating system experiences 'fictional' forces such as the centrifugal force on a boy swinging on a merry-go-round. Einstein was the first to recognize that fictional forces, induced by acceleration, are closely connected with gravitational forces. So in his generalized theory of relativity Einstein

showed that the laws of physics become invariant when the gravitational field is introduced into the equations of the physical laws. This means that if a set of physical laws is invariant under some global symmetry, the stronger constraint of invariance under a local symmetry transformation can be met only by introducing new fields which give rise to new forces. The fields so introduced are named gauge fields and they have to be associated with new mediating particles, like photon and π^-mesons, which will give rise to the corresponding forces. It is by recourse to such gauge fields in weak nuclear force that Salam has been successful to unify the weak and electromagnetic forces.

With the application of gauge invariance what Salam did first in 1956, was to predict two massive charged mesons of spin one (we call $W\pm$) to mediate in weak nuclear forces—analogous to photons in electromagnetism. This was criticized by Pauli when he wrote to Salam in 1957:

"There is a similarity between this type of gauge invariance and that which was published by Yang and Mills....However, there are dark points in your paper regarding the vector field β_μ. If the rest mass is infinite (or very large) how can this be compatible with the gauge transformation $\beta_\mu \rightarrow \beta_\mu + \gamma_\mu A$? Every reader will realize that you deliberately conceal here something and will ask you the same question."

It took Salam ten years to resolve this objection of Pauli. The problem of gauge symmetry was that it was only applicable to massless particles like photons. Salam had to develop a mechanism to dress his gauge particles, the intermediate vector bosons, with masses.

This was achieved through the concept of spontaneous symmetry breaking—the idea is that a quantum theory could possess an exact symmetry, and that the physical states might nevertheless not provide neat representations of the symmetry. In particular, a symmetry of the theory might turn out to be not a symmetry of the vacuum.

In uniting the weak nuclear and electromagnetic forces Salam has to treat the mediating vector bosons, $W\pm$ and γ, as members of one family coupled, respectively, to weak and electric currents with equal basic strengths. He noted that he cannot do so unless there exists a fourth vector boson, electric-

ally neutral denoted by Z^0, which is coupled to a neutral weak current which was then thought to be non-existent.

According to this theory, γ, $W^\pm$, Z^0 get coupled to their respective currents, with the coupling strengths e, $e/\sin\theta$ and $e/\sin\theta\cos\theta$ where θ is an angle determined by experiments. So Salam's unified theory predicted the existence of neutral current in 1967 which was, first, experimentally confirmed at CERN Laboratories in 1973. Because of this unified theory, there had to be a parity violation in electromagnetic interaction as the electromagnetic interaction and the weak nuclear force are different manifestations of the same force—and weak interaction shows parity violation.

This was a very crucial consequence of this unified theory and when parity violation in electromagnetic interaction in the conventional sense was observed at Stanford in 1978 in the scattering of polarized electrons off the deuterium target, there was almost a universal acceptance of the unified electro-weak theory of Salam which was also, independently, worked out by Weinberg.

The value of any theory depends upon the number of experimental facts it serves to correlate, and upon its powers of suggesting new lines of work. So the third prediction of Salam's unified electro-weak theory is that "there must exist two new heavy elementary mediating particles of the weak nuclear force (e.g. here W^+ and W^- have been considered as one particle where the other becomes its anti-particle) with masses 80 and 90 times proton mass, the first charged, the second electrically neutral (e.g. Z^0).

The European Nuclear Research Laboratory (CERN) is looking itself to produce the requisite energetic beams of protons and anti-protons with its new accelerator, commissioned a few years back. If sufficiently energetic beams can be produced, one may expect that during 1982-83 experiments, to check if the predicted particles exist, will be carried out. If such energetic beams are impossible to produce—and there are formidable difficulties in attaining the requisite intensity—one shall need a new particle accelerator with verifying energies and intensities still higher to check the matter. This "experiment—the existence of the electro-weak particles and in particular the heavy photon (Z^0)— is in some way on par with

the 1919 eclipse measurement of deflection of light which established Einstein's theory of gravity. This time it is the unification of the weak nuclear force with the electromagnetic which is at stake." This is what Professor Salam wrote in 1979.

Dr. Samuel Johnson, one of the most sagacious men of his age and the author of the first dictionary in English language, remarked in 1770 that "if Newton had flourished in ancient Greece, he would have been worshipped as a Divinity." This may also be said of Salam if experiments establish that the new heavy elementary mediating particles of the weak nuclear force do indeed exist in nature.

As the basic mathematical feature of the Salam-Weinberg theory is the 'gauge principle', it is believed at present that this principle can be extended to relate the strong nuclear force to the electro-weak.

On this point, Salam said in 1977:

"If we think of the strong nuclear force, could this also be of the same character as the electrical force? Then, to be more ambitious, can we ever realize the dream of Einstein that these three forces, joined together with gravity, can be shown to be aspects of one single force? The gauge principle permits such unifications, but unhappily, to verify these ideas would be almost prohibitive. One would need energies of the order of 10^5 GeV to make the unification between these forces apparent, and energies of the order of 10^{19} GeV to make a direct verification of the unification of gravity.

An accelerator of energy 10^5 GeV will probably never be built—it would need to have a radius of 200 kilometers (according to technologies available at present). So one will have to rely on indirect evidence.

This could be of rather an unusual kind. For example, some evidence could come about by studying the decay of proton. So far we have assumed that the proton is a stable particle. If the unification ideas of the strong force with the electroweak are correct, we predict that the proton will be found to decay."

Salam's work on unified electro-weak theory was first recognized by the Institute of Physics, London when Salam was awarded the Guthrie Medal and Prize in 1976 for his contributions.

"In recent years he has made important contributions to the quantum theory of gravity. Professor Salam anticipated

the crucial role of the two component neutrino in parity violation and correctly predicted the form of the weak interaction. Ten years later, he correctly predicted the existence of weak neutral currents on the basis of a unified renormalizable theory of weak and electromagnetic interactions."

In 1978 an avalanche of honours started for Salam. But I will quote here the address delivered by Lord Todd on the occasion of the award of the Royal Medal, the highest medal of the Royal Society, to Salam in 1978:

"Professor Salam has been a very prolific researcher in theoretical elementary particle physics. He did important work on renormalization theory and was one of a number of theorists who independently suggested the two-component neutrino. This added greatly to our understanding of the weak interaction. He was also one of the first people to realize the impotance of gauge field theories. However, his major recent contribution to particle physics is his unified theory of weak and electromagnetic interactions. It will be some time before all aspects of his theory can be checked experimentally and it may well be that it will need some minor modifications. But the Salam-Weinberg theory (the same idea was independently suggested by the American theorist Steven Weinberg) predicted the existence of the neutral weak currents that were discovered about two years ago at CERN and it remains the successful bench-mark with which all quantitative investigations of these currents are compared. The unification of the weak and electromagnetic interactions has been justly described as analogous to the nineteenth century unification of electricity and magnetism. It is an idea of the first importance.

Salam has also been active in promoting scientific research in developing countries. The Institute at Trieste, of which he is Director, plays a leading role in encouraging theoretical work in these countries by providing visitors with facilities for individual study and research."

The American Institute of Physics, an organization of nine physics societies representing the great majority of American physicists, named Salam for 1978 as the recipient of the Tate Medal. The Certificate of citation presented to Salam with the award reads:

"Founder of the International Centre for Theoretical Physics, Abdus Salam has contributed greatly to the progress of theoretical physics all around the world, by offering to scientists of all countries opportunities to collaborate productively. The numerous papers that originated from such collaboration have advanced knowledge in diverse fields of physics, from elementary particle physics to solid state physics. Under Salam's leadership the Centre gave unique opportunities to physicists from developing countries to collaborate with leading theorists from all around the World, thus increasing greatly the productivity of physicists at Universities in developing countries, strengthening scientific cooperation on a global scale."

In 1979, Professor Abdus Salam, along with Steven Weinberg and Sheldon Glashow, was awarded the highest honour in Physics — the Nobel Prize — for his work on the theory of the unified weak and electromagnetic interaction between elementary particles, including inter alia, the prediction of the weak neutral current, by the Swedish Academy of Sciences in the light of the recommendations received from the Nobel Committee. The Nobel Committee's recommendations are based on the proposals received from various sources. The right to submit proposals to the Nobel Committee for the award of the prize, based on the principle of competence and universality, is enjoyed by:

1 Swedish and foreign members of the Royal Academy of Sciences;
2 Members of the Nobel Committee for Physics;
3 Nobel Laureates in Physics;
4 Permanent and acting professors in physics at the Universities and Institutes of technology of Sweden, Denmark, Finland, Iceland and Norway, and at Karolinska Institute, Stockholm;
5 Holders of physics chairs in at least six universities or university colleges selected by the Academy of Sciences with a view to ensuring an appropriate distribution between different countries and their seats of learning; and
6 Other scientists from whom the Academy may see fit to invite proposals.

Professor Salam describes the Nobel Awards ceremony as follows: "The Nobel Prize ceremony is a wonderful experience. For ten days we were the guests of the King and Queen of Sweden. We were accommodated in the Grand Hotel with our families. The awards ceremony is rehearsed on the morning

of the award. On the day the awards are presented, the King and Queen wait for you and your arrival is announced with the blowing of a trumpet. When the trumpet sounds, you walk along and when it stops you also stop. A citation is read and then again the trumpet sounds. You receive the prize and bow to the King and Queen and walk back.

After the ceremony is the Banquet with 2,500 seated guests—2000 Swedish men (and women) of nobility and affairs and 500 students. All the courses arrive to music, carried by waiters in beautiful uniforms. The colourfulness and grace of the ceremony is indescribable. During the banquet, one prize winner from each subject is asked to give a three-minute banquet address, to trumpets again. I was asked to respond to the toast of Physics and here is the text of my reply.

Your Majesties, Excellencies, Ladies and Gentlemen,

On behalf of my colleagues, Professor Glashow and Weinberg, I thank the Nobel Foundation and the Royal Academy of Sciences for the great honour and the courtesies extended to us, including the courtesy to me of being addressed in my language Urdu.

Pakistan is deeply indebted to you for this.

The creation of Physics is the shared heritage of all mankind. East and West, North and South have equally participated in it. In the Holy Book of Islam, Allah says:

"Thou seest not, in the creation of the All-merciful any imperfection, Return thy gaze, seest thou any fissure. Then Return thy gaze, again and again. Thy gaze, Comes back to thee dazzled, aweary."

This in effect is, the faith of all physicists; the deeper we seek, the more is our wonder excited, the more in the dazzlement for our gaze.

I am saying this, not only to remind those here tonight of this, but also for those in the Third World, who feel they have lost out in the pursuit of scientific knowledge, for lack of opportunity and resource.

Alfred Nobel stipulated that no distinction of race or colour will determine who received of his generosity. On this occasion, let me say this to those, whom God has given His Bounty. Let us strive to provide equal opportunities to *all* so that they can engage in the creation of Physics and science for the benefit of all mankind. This would exactly be in the spirit of Alfred Nobel and the ideals which permeated his life.

Bless you!

Chief Scientific Advisor to President of Pakistan (1961-1974)

Salam was introduced in the corridors of Power in Pakistan, the first time, by Mian Iftikharuddin who, in his own daily newspaper, inspired a long article entitled:

"Pakistani Physicist makes his outstanding contribution".

Mian Iftikharuddin was a cultured intellectual and a shrewd politician who joined the Muslim League by resigning from the position of the President, Punjab Congress Party, in 1946. He met Salam in London in 1957 while on a visit to the U.K. to get his son Arif admitted there.

With the colonial indoctrination for the intellectual inferiority of the Asians and the historical void among Muslims in mathematical knowledge, Mian Sahib was unspeakably astonished and impressed when he learnt that Salam had been appointed a professor in Britain. It was during that period when, in a series of articles published in the *Pakistan Times*, a ghost author, probably Dr. M. D. Taseer, perceived that when "Pakistan rules Britain", then a Pakistani would get appointed a professor of Urdu in England; so with this background at the back of his mind, Mian Iftikharuddin, on return to Pakistan, got this article in print in the *Pakistan Times*, dated 25 August, 1957.

The immediate effect that this article generated was to move the Punjab University to honour Salam by conferring on him an honorary degree of D. Sc. in December 1957. Then coming into power in 1958, Muhammad Ayub Khan, along with the Duke of Edinburgh as a distinguished guest, inaugurated the Pakistan Science Conference in the University of Karachi where Salam met the President after the Conference. President Ayub asked Salam to advise the Government in the purchase of an appropriate power reactor. Dr. Nazir Ahmed was then the Chairman PAEC. As a consequence of this conversation Salam was appointed a part-time member of PAEC and on his suggestion Dr. I. H. Usmani, a CSP with a Ph. D. in Physics working at that time as Controller of Imports and Exports, was inducted as a full-time member with the implicit understanding that, on Dr. Nazir Ahmad's retirement, Usmani would take over as new Chairman, PAEC. In 1959 Salam was associated as Adviser to the Education Commission and a member of the Scientific Commission in Pakistan. In his inaugural speech at the first session of the Scientific Commission, on August 4, 1959, President Ayub said: "In the end, I must say how happy I am to see Prof. Abdus Salam in our midst. His attainments in the field of science at such a young age are a source of pride and inpiration for us and I am sure his association with the Commission will help to impart weight and prestige to the recommendations."

A detailed account of the period of Salam's involvement in the organisation of science in Pakistan brings in some difficulties including a sort of personal detachment, that I lack. In addition all through the written history of mankind, it has indeed been a very dangerous thing to look too closely into the workings of one's own society. I have, therefore, limited myself to the task of highlighting the contributions of Salam's efforts to develop science and train scientists in Pakistan.

His immediate priority in Pakistan was to train scientists. He succeeded in persuading S.M. Sharif, the then Federal Secretary of the ministry of education, with an all-out help from S.G. Khaliq, an O.S.D. in the education department, to allocate funds for six yearly scholarships for post-graduate studies in physics. This scheme continued for three years and helped persons like Riazuddin, Fayyazuddin, Munir Rashid

and others to pursue their Ph. D. studies in the U.K. Simultaneously, at his urging, an extensive training programme was also launched in PAEC to develop scientists and engineers in various nuclear fields. For Salam to chart out the dynamic role of science in a static Muslim society was not a simple task. It meant the introduction of effective attempts for utilizing the scientific method and outlook to release the social order from many of the disorders which it has afflicted to over the last few centuries. There were many problems present in administration, education, the penal system, public health, industrial growth and the economic life of the nation in which a proper supply of scientifically ascertained facts was an indispensable preliminary to applying scientific methods in determining wise actions for their reorganization.

Salam knew that Pakistan had neglected to develop, organise and use the nation's intellectual resources. He also had experienced that the shortage of scientists was due to the fact that the career of a scientist in Pakistan was most precarious and the government had exhibited a complete lack of imagination and had therefore failed in developing, conserving and mobilizing scientific manpower in the country. His remedy was, first to train scientists and to increase endowments to Universities for scientific teaching and research and to make them comparable to western Universities; second to create a National Scientific Council and the ministry of science and technology by deploying one percent of national income on trained research workers, laboratories and scientific equipment in the best interests of national welfare.

Salam was also instrumental in persuading the Government of Pakistan, through President Ayub, of the national need to the creation of the PINSTECH Laboratories in Islamabad (Institute for Nuclear Science and Technology) for which an amount of rupees one hundred million was sanctioned—the amount that was partly well-spent and partly mis-spent on the laboratories' buildings and the scientific equipment by the full-time salaried science administrators in the country. For the nuclear-power programme of the country he advised the Government to set-up a 140 Megawatt Power Reactor in Karachi with natural uranium as fuel and heavy water as moderator for slowing down the fission

neutrons. For carrying out missile research and development, Salam founded the Space and Upper Atmosphere Research Committee (SUPARCO) and was for a while its chairman.

Salam's greatest contribution in the social sciences, in my assessment, has been his presidential address at the Pakistan Association for Advancement of Science held in January 1961 at Dacca.

On his way to Dacca he stopped in Karachi where the temporary laboratories of PAEC were then established at West Wharf, including an active research group engaged in the study of meson-interaction employing emulsion technique. Professor Salam had invited Sir John Cockcroft, the founder of Atomic Energy Research Establishment, Harwell and Nobel Laureate of 1951 "for the pioneer work on the transmutation of atomic nuclei by artificially accelerated atomic particles", to visit these laboratories. In the morning the emulsion group discussed as usual a certain physics problem on the blackboard. Then before Cockcroft was to come into the emulson room, the Director of the laboratories, a physicist not involved with the emulsion group research, was seen standing near the blackboard rubbing off all that was written on it. However, a few minutes later Salam entered the room and asked the research scientists why it looked as if the blackboard had never been used: he immediately called them at the blackboard and started discussing a certain problem. At that moment Cockcroft came in and observing Salam explaining the meson interaction complexities remarked: "Oh you have already established your research group". This is just a glimpse of the general scene depicting how our society works at cross purposes.

At Dacca Salam talked on "Technology and Pakistan's Attack on Poverty"—a topic still of increasing relevance and over-riding priority to Pakistan. In his exquisite address Salam quantified the economic laws of development urging Pakistan to adopt them for eradicating poverty from its teeming millions.

Salam spoke: "There are times when, in all humility, a mere scientist may also express himself on ideological matters, not because he has new insights to reveal but because there are things he believes passionately in, which need saying and cannot be said often enough.... We, in Pakistan, are very

poor. This poverty we share with the majority of the human race, with some one thousand million people in about a hundred countries....This uneven distribution of wealth is relatively of a recent origin. Three hundred and fifty years back Akbar's India and Shah Abbas's Iran compared favourably in living standards with Elizabeth's England. Soon after, however, the western growth started. It coincided with a great technological advancement in agriculture and manufacturing methods.... What, however, distinguished the nineteenth century technological revolution was the fact that it was firmly based on a scientific mastery of natural law....The last hundred years have seen nation after nation starting with something like our conditions and crash through the poverty barrier. The laws governing this type of transformation are now well understood".

Salam continued: "First a society must acquire the requisite technological skills, secondly it must save and re-invest more than five percent of its national income in productive enterprises". He said: "To double the standard of living in forty years needs an investment rate of ten to fifteen percent; to double it in a decade, a nation needs to invest about twenty-five percent of its national income."

Emphasising skill and capital Salam elaborated: "These then are the two prerequisites for building up a self-reinforcing economic growth. Nation after nation has acquired this in the last two centuries....Four of these experiences—those of Britain, Japan, Russia and China—however, stand out clearly".

According to Salam: "The British showed that the poverty barrier can be crashed through if skills and capital are available. The Japanese showed that technology is communicable; that it is easy to learn and acquire. Japanese experience forced home the moral that technological competence is not a hereditary characteristic; that it can be acquired and in fact acquired rather quickly. Russia showed that transition to sustained growth need not take a century or longer. It can be telescoped into the span of one man's life provided heavy industry receives top priority. And then finally there is the Chinese experience underlining that cheap labour is itself a form of capital".

Referring to the United States, Salam commented: "Their prosperity is due to an organisation of society where scientific knowledge is fully exploited to increase national productivity. This prosperity is a portent of hope; hope that possibly within our life time, using the same methods, we in Pakistan may also achieve the same".

Salam emphasised: "Our poverty raises not merely material but also spiritual issues. The Holy Prophet, (may peace and blessings of Allah be upon him) said: "it is near that poverty may become synonymous with *Kufr*". Let me say with all the vehemence at my command that I would like to see this saying of the Prophet (peace be upon him) on the doorpiece of every religious seminary in Pakistan.... There may be other criteria of *Kufr* as well, but in the conditions of the twentieth century, in my opinion the most relevant criterion of *Kufr* is the passive toleration of poverty without the national will to eradicate it".

Now when in 1981, we look back at our history of development, one may probably say that, in all earnestness, we have passively tolerated poverty in our midst. And according to Dr. Johnson, "he that voluntarily continues ignorance and poverty is guilty of all the crimes which poverty and ignorance produce; as to him that should extinguish the tapers of a lighthouse, might justly be imputed the calamities of shipwrecks". To emphasize the vital necessity for the emergence of an enlightened political leadership for a successful attack on poverty Salam quoted Rostow's words that: "The nation not only awaits a surge of technological development in agriculture and industry, but it also needs the emergence to political power of a group prepared to regard the modernisation of the economy as a serious high order political business—such was the case in Germany with the revolution of 1848, such was the case with Japan with the Meiji restoration of 1868, such was the case with the Russian and Chinese revolutions".

Finally Salam concluded his address: "Let us be absolutely clear about the nature of the revolution we are trying to usher in. It is a technological and scientific revolution and thus it is imperative that top-most priorities are given to the massive development of the nation's scientific and technological skills... let future historians record that the fifth important lesson in

economic transition to prosperity was taught by Pakistan in achieving a rate of growth as rapid as the Russian and the Chinese but without the corresponding cost in human sufferings." This was Salam's preaching in 1961 at the age of thirty-five. Late in the seventies Salam divided his two decades, as an exile, into two distinct categories—the first decade 1954-64, as the decade of innocence and hope and the second decade, 1964-74, as that of growing frustration and a feeling of hopelessness

Salam's incisive and persistent analysis on the human history of economic development in his "Technology and Pakistan's Attack on Poverty" rivetted everyone's attention; as the cumulative impression was of stupendous brilliance and one scarcely knew whether to admire most the knowledge and experience expressed so vividly, the strategy employed, the relentless energy spread in the address or the daring to reflect on the various alternatives revealing sensitively the germination of his revolutionary ideas and emotions. As he looked dangerous for the established order of society, he was to be tamed and harnessed and consequently, at least as I interpret it, he was appointed the Chief Scientific Advisor to the President of Pakistan the same year.

Salam was reluctant to lose his innocence by accepting the honorary position of Chief Scientific Adviser, as he was fully conscious of the fact that it was not sufficient to discover and prove a useful truth but it was also necessary to be able to propagate and get it recognised and implemented; and he clearly perceived that he would not be able to do it from abroad against hurdles and lack of appreciation on the part of the bureaucracy. When the President wanted to sign the document Salam was called at the government house Lahore where the President was then staying. He was on the verge of saying no when Qudratullah Shahab, then Secretary to the President, intervened. It was he who prevailed upon Salam to accept the honour assuring him that all the help would be forthcoming to get his suggestions and recommendations implemented in the field of Science and Technology in Pakistan.

According to Shahab, President Ayub wanted Salam to work in Pakistan on full-time and salaried basis whereas

Salam's preference was to have a part-time and an unpaid status which would not cause a destructive interference with his researches in high energy theoretical physics at Imperial College, London. Shahab observed that with Salam's appointment as scientific adviser to the President, the post-graduate scholarships for scientists and engineers were increased many-fold and scientific projects recommended by Salam got direct support from the President for their implementation Later on the Ministry of Finance started objections that the Government was not getting its money's worth in return for the amount spent on scientific work. The ministry was of course oblivious of the situation that the organisation of science has to attain a certain critical level in manpower, expenditure and its overall organisation before science's benefits start flowing directly and rapidly to the public at large. And only at that critical level, its significance as a multiplier of wealth gets that obvious where the limiting factor becomes not the amount of money available for expenditure but the number and the quality of scientists who can use that money As a Chief Scientific Adviser, Salam continued to draw public attention to the lack and neglect of science and scientific education in Pakistan. He wondered that why the nation's educational conscience had not been strung by the obvious thought that it had neglected science. For him the trusting of luck in accepting poverty was a mark of the dangerous complacency bred of ignorance, as the success to economic prosperity depended largely on the possession, by the national leaders and administrators, of the scientific method and the scientific habit of mind; and Salam exercised all his tact and influence to convince them that drastic reforms in college and university education were necessary for the national welfare. He developed a permanent theme that a nation superbly trained in scientific method and scientific habit of mind and agitated with an enthusiasm for scientific knowledge would no doubt attain comfort and prosperity, but its greatest reward would be that it would be equipped with a deep and generous education to carry out skillfully and justly the duties, both public and private, to strengthen the security and prosperity of its country.

For him the teaching of science, also, had several distinct kinds of educational value. As he had himself experienced,

science arouses and satisfies the element of wonder in our natures, stimulates curiosity, quickens and cultivates directly the faculty of observation, teaches the learner to reason from his own noticed facts, disciplines the powers of mind and awakens the thinking powers, encourages an attitude of criticism and strengthens the power of rapid and accurate generalisation. So science is a valuable vehicle in opening the mind, in training the judgement, in agitating the imagination and in cultivating a spirit of reverence. Science's utility and applicability are obvious through its necessity in war, in defence, in offence and in the prosperity of industries and trade—all this led Salam to crusade for wider and higher science teaching and research in Pakistan.

Referring to science and technology Salam once wrote: "Technical Competence and material prosperity have become synonymous and it is this cardinal fact that the poorer two-third of humanity is beginning to realize. It is this cardinal fact that the developing world must come to grips with today".

To illustrate that these material inequalities are not very ancient, Salam wrote: "I shall start my story about three centuries ago. Around 1660 two of the greatest monuments of modern history were erected....one in the West and one in the east—St. Paul's Cathedral in London and the Taj Mahal at Agra in the India of the great Mughals. Between them these two monuments symbolize, perhaps better than words can described, the comparative level of craftsmanship, the comparative level of architectural technology, of affluence and sophistication the two cultures had achieved at that epoch of history. But at about the same time was also created, and this time only in the west, a third monument, a monument still greater in its eventual import for humanity. This was Newton's Principia published in 1687.

Newton's work had no counterpart in the India of the Mughals. The impulse-springs of Islamic Science had dried up earlier. The Taj Mahal was about the last flowering of a tradition, a tradition that was no longer creative, a tradition that was soon to wither and die."

With this level of perspective in history, Salam urged President Ayub in Pakistan to support and sanction the creation of Pakistan Institute of Nuclear Science and Technology—a

creative scientific monument to revive scientific culture in Pakistan, and this appealed to Ayub as a sound advice and so PINSTECH was created at NILORE in Islamabad.

International Centre for Theoretical Physics

While earning the adverse remarks in his annual confidential report from his principal for attending a scientific discussion in Bombay, Salam had already sworn that he would continue to try to create a mechanism which helps to end isolation of gifted individuals while they still live and work in their own countries. He wanted both a place where physicists from developing countries could freshen their ideas and where scientists from everywhere could do research of the highest order and he wanted it in Pakistan. So in 1960 he thought of the idea of establishing an International School for Theoretical Physics, under the auspices of the IAEA. In 1963, Salam requested President Ayub for a generous offer from the Pakistan Government to get this Centre established in Pakistan. In Salam's presence President Ayub asked for advice, on the telephone, from his finance minister, who replied "Sir, the professor is trying to set up an international hotel for the world scientific community—and not a school of theoretical physics in Pakistan".

Salam relates in detail how he, in September 1960, first proposed the school: "I had the privilege of attending the General Conference of the IAEA as the delegate from my country. With the co-sponsorship of the Government of Afghanistan, the Federal Republic of Germany, Iran, Japan, the Philippines, Portugal, Thailand and Turkey, we introduced a resolution on behalf of the Pakistan Government suggesting the setting up of a theoretical physics centre under the auspices of IAEA. Right from the outset the idea met with enthusiastic support from the IAEA directorate, particularly from its distinguished Director General Dr. Sigvard Ekland. Two of our most ardent sponsors were Niels Bohr and Robert Oppenheimer ....After four years of intense behind-the-scenes effort, the Board of Governors of IAEA agreed to set up such a Centre for a trial period of four years provided the bulk of the finance for it could be found outside the IAEA funds. The most

generous was the Italian Government's offer for Trieste. This offer was accepted and the Centre started functioning in October 1964 with a mandate until October 1968." The Centre received as visitors, leading physicists from ninety-seven countries, eighty of them developing. With the generous grant from the Ford Foundation and some from UNESCO, the Centre pays the associate's fare and his expenses at Trieste. An Associate is a physicist working in a developing country who is simultaneously a member of the Centre's staff for a period of 3 to 5 years which is renewable.

Salam says: "I recall that during the 1962 general conference of the IAEA, after the voting had gone in favour of the creation of this Centre, a dear friend who was an adviser to the United States delegation (a physicist and Nobel Prize Winner) turned to me and said: "Salam, you have succeeded in having voted in a Centre for the developing countries, but so far as physics is concerned it will be a developing Centre." I said: "Professor....I promise you that it will be a Centre of such quality that in time you will feel honoured to receive an invitation from it." By 1968, I was able to invite my friend to visit us here. He was generous enough to write back that he was indeed honoured to come to a Centre of such great reputation in physics...."

Eight Nobel Prize Winners attended the International Symposium on Contemporary Physics in 1968. In all branches of physics that the Centre has touched since 1964, the world's best have come to Trieste to give of their time for little compensation, a contribution that cannot be quantified. By the end of 1980, the number of scientists visiting the Centre every year was running around 1,600 and an estimated 10,000 had been able to benefit from it since it was opened. Salam considers this Centre as his greatest direct and most successful contribution to mankind's progress and prosperity. And most of those who know the Centre agree with him.

Salam continues to propound the desirability of establishing more such Centres at the international level. Quoting Gunnar Myrdal, Salam argued: "There is no human more arrogant than the economist who receives a three-year Ph. D. training, at the end of which he believes that he can draw up a plan of development for his country for the next decade in a matter

of one wakeful night. The science post-graduate, after three years, becomes a cripple. He refuses to look at any research field except the narrow one in which he is specialized.

This is the tragedy of the scientific training imparted by our Universities. For rich countries, it does not matter so much. There is so much opportunity to learn after one has taken his Ph. D.

For the developing countries, there is no such opportunity. And this is where a centre such as ours comes into the picture." On another occasion, Salam wrote: "He (physicist) needs the stimulus of hearing the rare men of genius expounding the ideas which have changed or are changing the whole direction of his subject; he needs regular discussion with the active workers who are busy exploiting these advances....The greatest enemy of creativity for those living in developing countries is their isolation....The only rational, logical solution to this dilemma appears to be the setting up of international centres for theoretical physics functioning under the auspices of the United Nations Organization". By this time he seemed to have lost hope that developing countries would do anything at all on a self-reliant basis!

Swat Science Conference at Saidu Sharif

With Salam's initiative an exclusive science conference, attended by the country's top-most scientists who were invited by special invitation from the Scientific and Technological Division, was organized in the presence and with the patronage of President Ayub Khan in Swat at Saidu Sharif in August 1965. There were formal and informal discussions for two days with mysterious clouds casting suspense in the atmosphere; trouble had already started in Kashmir leading to murmurs of war from India. On the last day of the Conference Salam looked troubled and saddened and while sitting in a car with me reflected inaudibly, "Nothing meaningful would come out of this ill-thought out pending war except that many of our flowering patriotic youth would get sacrificed."

In his address to the President of Pakistan as a Chief Scientific Adviser he said: "The first occasion when the place of science in society received due recognition was when you

wrote: "The abundance of agricultural riches which our soil's bounty provides us owes its origin to the superb irrigation system—the largest in the world, irrigating some 23 million acres—which the British left us as a legacy of 19th Century dam-building technology....the truth is that no amount of imported technology without very strong indigenous backing will lead to a longterm solution of the problem of under-development. The developing world has been importing black-box technology for at least half a century. If anything, this has magnified their under-development.

Technology, in order to take, in order to get assimilated into the fabric of a society, in order to become part of its tradition, needs a strong local base of scientific knowledge and skills. Before a true technological revolution can come about, this base will have to be created. And for the creation of this base, for the creation of the instinct of what is credible and what is not, what is scientifically and technologically genuine and what is deceptive, there is nothing as potent as the direct experience of living science—living in one's own conditions and environment, and flourishing within one's own cultural tradition....

He said: "Waterlogging and salinity are as old as irrigation itself. It has also been known for long that proper drainage is the only answer, but what makes horizontal drainage impossible in the Indus plain is the unfortunate circumstance that the plain slopes no more than a foot per mile. Horizontal drainage would be prohibitive in cost. The Revelle team suggested vertical drainage instead....mining of fresh water from an underground reservoir, known to exist, by a network of deep tube-wells. Some of the water would seep back underground, leaching away the salt in the process. Also the general lowering of the water table on account of the pumping would cure waterlogging. Vertical drainage had in fact been tried in Pakistan for the last fifteen years, but the results were discouraging.

The great contribution of the U.S. team was to stress that the difficulty came from using the method on too small a scale. A single well, for example, has no effect on the water level because water seeps in from the surrounding areas as fast as it is removed. To achieve a substantial lowering of the water

table one must exploit the simple fact that with increasing size of the surface, the area increases more rapidly than the perimeter—the same principle which in wartime Britain made the British decide in favour of large trans-Atlantic convoys as affording better protection against submarine peripheral attacks rather than convoys of tiny size. Revelle's calculations—using extensive digital and linear programming at Harvard—showed that if one dealt with an area no smaller than one million acres (roughly 40 sq. miles) the peripheral seepage would not win against the area pumping: one might then hope to eliminate waterlogging within a year or two.

Other Contributions

With a constant worry for undeveloped countries' economic poverty and its causes, Salam, in 1963, mentioned Al Asuli, a great Muslim physician who divided his pharmacopoeia into two parts, "diseases of the rich" and "diseases of the poor," and wrote: "If Al Asuli were alive today and could write about the afflictions of mankind I am sure he would again plan to divide his pharmacopoeia into the same two parts. Half his treatise would speak of the one affliction of rich humanity—the psychosis of nuclear annihilation. The other half would be concerned with the one affliction of the poor—their hunger and near starvation. He might perhaps add that the two afflictions spring from a common cause—the excess of science in one case and the lack of science in the other".

Quantifying his country's poverty Salam wrote: "Fifty percent of people in my country of Pakistan earn and live on eight cents a day. Seventy -five percent live on less than fourteen cents. These fourteen cents include the two daily meals, clothing, shelter and any education they can get."

Switching over to the nuclear arsenal he wrote: "For us, the nuclear problem is tragic only in that it leads to a criminal waste of the earth's resources. For me personally it is tragic for it claims the last ounces of the strength of some of the greatest sages of our age—sages like Bertrand Russell who may otherwise have preached the immediate crusade against hunger and want." Raising a question "but why are we poor"? Salam answered: "Mostly no doubt through our own follies.

But let me humbly suggest that it may partly also be that we are financing some of the prosperity of the rich. Year after year I have seen the cotton crop from my village in Pakistan fetch less and less money; year after year the imported fertilizer has cost more". For the eradication of poverty Salam proposed a condensed plan of action in these words: "It consists largely of taking stock of a country's natural resources. It consists of the long process of acquiring some of the well known technical skills. It consists of making an imaginative assessment of which of the resources can be technically exploited most expeditiously within the human and material means at one's disposal."

Along with this proposal he introduced a note of caution by writing that "in most undeveloped countries there are few men who can make the right lists of priorities", implying that their education system was inferior and defective lacking the desired content and quality of scientific instruction and research.

At another occasion, at the university of California, Salam spoke rather philosophically: "It is fully possible that a new phase of industrialization may come, this time financed by loans from the World Bank and helped by experts from abroad but this phase may leave the heart of the country so far as development of indigenous technical talent is concerned, as untouched as ever before. And there is real danger that this could happen, for the World Bank or any other aid-giving agency, with the best will in the world. is interested more in the completion of a project in the shortest possible time rather than in seeing that it should have been executed by the Pakistani technicians to give them the requisite confidence and experience —there are other dangers too....the nightmare, for example, of the discontinuance of foreign aid programme".

Feeling sensitively that the economic inequalities in a poor country are more disturbing than those in an affluent society Salam explained: "We face in this respect a dilemma peculiar to most developing countries; in a growing polity there is nothing more destructive of morale than economic inequality. In a country where general affluence prevails, large differences of income can perhaps be tolerated, but not if the bulk of your population is at a starvation level....our dilemma is, how does

one continue providing opportunities, and the disproportionate inequalities they must produce, from affecting general morale"?

An international seminar in Nuclear Physics was organized in 1967 at Dacca where PAEC laboratories had already commissioned a four MeV Van de Graaf accelerator to conduct research in proton interaction. Some of the top nuclear physicists from Europe and the USA were invited, through Salam's personal contact and influence, to participate in this seminar. In his inaugural address at this seminar Salam remarked: "Almost exactly twelve hundred years ago, Abdullah Al Mansur, the second Abbaside Caliph, celebrated the founding of his new capital, Baghdad, by inaugurating an International Scientific Conference....Al-Mansur's Conference succeeded beyond all expectations. It laid the foundations of astronomical and mathematical studies in Islam; out of this Conference grew the idea of the founding of one of the world's first International Academics for scientific research, the *Bayt-ul-Hikma.* But even on the more practical, more pragmatic plane, from the Conference dated the architectural and engineering studies of *Naubakht* and *Mashallah*, both of whom attended its sessions and who were later responsible for some of the major monuments of Baghdad. From this Conference dates the craft of instrument making in Baghdad, the specimens of which still survive in the masterworks of Isa Asturlabi.

No one can say whether the contributions at our meeting today will in retrospect of history make this symposium appear as significant for nuclear science itself as that meeting at Baghdad. But in all humility let me say this; this first International Symposium on Nuclear Science will inevitably quicken the pulse of the subject in Pakistan. The fact that we are so fortunate as to welcome so many distinguished and leading world physicists today betokens that work done at the centre at Dacca is of world quality; it is a portent of the hope that the community in Dacca, and in Pakistan, normally so isolated, will become integrated as part of the main stream of the international centres of significance receiving and, I hope, giving as well."

Talking of the difficulties faced in carrying out advanced scientific research in developing countries Salam said in

1968: "Unfortunately, research is costly. As we have seen, most countries do not yet feel it carries a high priority among competitive claims for their resources. Not even indigenous applied research can command priority over straightforward projects for development. The feeling among administrators, perhaps rightly, is that it is, by and large, cheaper and perhaps more reliable to buy applied science from the world market. The final picture, so far as advanced research is concerned, remains almost as bleak as at Kandhar (in A.D. 1470).... To me, the first and foremost determining factor for all advanced research is the supply of towering individuals, tribal leaders, around whom great institutes are built. These are perhaps five percent of all the men who are trained for research. ...To me it is astonishing, miraculous, that considering all the hazards that beset a poor society, any talent at all is saved for science."

Yahya's Period 1968-71

Salam has always felt that: "We should go to the limit of what we can do. We should not speculate and worry about not being able to do things. Somehow or other the idea of despair just does not enter my mind". Probably this is the attitude of all great men as all men who achieve eminence and those who are naturally capable, are, to a large extent, identical—possessing the qualities of intellectual capacity, zeal and industry. So despite the fact that Salam was hardly consulted for advice by Yahya Khan's Government during 1968-71, he did not lose hope but wrote a comprehensive paper, "Toward a Scientific Research and Development Policy for Pakistan" in which he emphasized: "Our major resources are three: (1) natural gas; (2) rich alluvial soil, provided it can be irrigated in West Pakistan and protected from floods in East; (3) abundant man-power provided it is skilled. These skills include agricultural, science, engineering and mathematics....There are three things wrong with Pakistan's research effort in science and technology:

(i) Small absolute size of science in relation to the economy's technological needs and to the country's cultural sophistication.

(ii) Neglected development of the research effort in certain important spheres; and

(iii) Lack of contact with international science.

These shortcomings basically stem from the same cause; Pakistan has never had a coherent science policy.... The total expenditure on research and development represented one-eighth of one percent of Pakistan's national product. In most advanced countries of the world the corresponding expenditure ranges between 2-3 percent of G.N.P. and one percent for developing countries like India, Korea, Formosa and Brazil".

"At present Pakistan imports technical know-how, technical processes, plant and in some cases basic raw-materials in the following fields:

(1) Most manufacturing and fuel refining industries;

(2) Tele-communication, transport and power (including atomic power);

(3) Medicine, pharmaceuticals and fertilizer manufacture.

By and large it would be unrealistic to hope that Pakistan Science could soon compete with the enormous research and development effort which has gone into the developing of processes and know-how which the country imports. A wise science policy in these areas would attempt to channel the local effort and this effort would have to be massive to yield economic returns—towards a well coordinated adaptive, substitutive and complementary role. It is important to realise that it is this crucial type of supporting effort which, for countries like Japan (till recently importing most of their know-how), absorbed as much as about 1.5 percent of the G.N.P. compared to our one-eighth of one percent."

"Perhaps the most unfortunate example of a totally neglected sphere is university science. It is unbelieveable but true that Pakistan has by and large no tradition of graduate school training. To take just one instance of this; the premier university of Pakistan—the Punjab University—in its one hundred years of existence has produced not a single Ph.D. in mathematics. In Pakistan the words "centre of excellence" have become current in speaking of university research schools.

Unfortunately, the usage somehow gives the impression that graduate research schools of moderate quality already exist and that some of these, when provided with further resources, could attain world class. This is just not so. In most universities, in most subjects, no post-graduate schools of any quality exist at all. I am pleading here for the academic and financial provision of normal post-graduate research facilities —not in every department in every university, but in most.

This will necessitate doubling or trebling present staff and providing funds to them for purchasing some decent teaching and research equipment. The hope could be that some of the funds for such postgraduate schools will be provided by the University Grants Commission and more importantly from the analogue of a National Science Foundation which we must create. These schools will give Ph.D. training, obviating for the most part the need for foreign post-graduate training."

Salam continued: "If there is one reform which I consider absolutely basic to the entire future of scientific research in Pakistan it is the massive provision for research—and its separate funding—in the universities. Without this reform, Pakistan science can have no strength, no backbone, no real future."

"Research does not thrive in an atmosphere where the command structure, career opportunities and procedures for acquiring needed equipment and facilities are those of a Govt. executive department....It is imperative that the universities place emphasis on developing graduate schools for research training within Pakistan. To help in this and to sponsor the universities' research effort in basic sciences it is essential that an analogue of the National Science Council in the United States or the Science Research Council in the United Kingdom be created to make post graduate research training awards, to give research fellowships and to make grants for purchase of equipment."

On isolation he said: "There is a need for a comprehensive policy and for funds to end isolation of Pakistan Science and Scientists from world science. There is need for liberalization of leave measures, need for funding of frequent visits abroad, for liberality and simplicity in import of literature and equipment. Pakistan must be one of the few countries in the world

where the attendance of a scientific conference abroad needs routinely permission from one provincial and three central Ministries."

He ended his paper by emphasizing: "One aspect of the international character of science is that its norms are also international, whether they refer to expenditure per scientist or to the service conditions under which his work can flourish. This must always be remembered if we expect internationally-normed returns on the monies spent on science in Pakistan". Salam considers his one contribution during Yahya Khan's regime to be the inspiration he gave to Mr. M. M. Ahmad, Finance Secretary during that period, to make a provision of Rupees one crore (later reduced to fifty lakhs) for founding the Pakistan Science Foundation. The idea was worked out during 1969-1970 when Mr. M. M. Ahmad was staying with Salam at his home in Putney, London.

Bhutto's Period 1971-74

In December 1971 Mr. Z.A. Bhutto took over as President of Pakistan. In the scientific gathering held at Multan in early 1972, Mr. Z.A. Bhutto as President and Chief Martial Law Administrator, decided that Salam, who commanded international recognition and admiration for his scientific achievements would continue to serve his government as Chief Scientific Adviser to the President. Salam agreed because he felt the country may be turning over a new page with a new regime, at least so far as science and technology were concerned, and there was euphoria in the air. Once again he was to be disillusioned.

Since 1960 Salam had been one of the most important exponents of the usefulness of science in improving Pakistan's productiveness and her standard of living. By 1974 he had begun to feel very despondent. But it seems that governments of the developing countries create illusions by false inspiration, attractive promises of development for future hope, talks of experts for economic prosperity, refer to confused analogies, and merely amuse themselves with administrative and scientific reforms and reorganization of society on paper without any programme for its implementation. They use these acts as

substitutes for painfully persistent and unremitting efforts required for progress through the development of science and technology in their societies. All too often there are slogans, then a leader, then corruption, then inefficiency, then extravagant promises, then delay, then disappointment, then disillusion, then resentment and contempt for human nature, then disregard for public responsibility and finally any convenient action to get even with the leader; and then new slogans. The low cultural and political level of the great majority results in short-sighted pursuits of their selfish interests without any realistic awareness of the common interests at the national level. The need is for an inspired leadership—capable of creation and collaboration for developing science and technology of the twentieth century. The Islamic system has not operated for the past centuries as it lacked the sufficient number of men who had a deep, clear grasp of its practical problems thrown out by the industrial society. Its men also lacked the political skill, zeal and faith to exercise it amidst the rival philosophies of capitalism and communism. The problems of creating a great Muslim society are immensely greater than many of us have been taught and induced to believe. We would have been better equipped to deal with them if we had identified and understood their correct nature and the magnitude of the difficulties involved.

So far as Salam is concerned, as his interest had already spread far beyond the tasks which were his main concern, he identified the two schools of thought regarding the charting out of a comprehensive programme for the Islamisation of society. There were people who believed that personal purification, on an individual basis, through *Zakat*, fasting and prayers in particular, would automatically revive the ancient glories and achievements of Islam for mankind in the twentieth century. As these had failed to be revived, the second school believed that the revival of Muslim nations is crucially dependent on the development of modern scientific culture as an integral part of the process of Islamisation and for eradicating poverty and ignorance from the Muslim societies.

This led Salam to propose the establishment of the Islamic Science Foundation on the occasion of the First Islamic Conference held at Lahore in 1974. In his note Salam proposed

the creation of a Foundation, by Islamic countries, with the objective of promotion of science and technology at an advanced level. "The Foundation (working in conjunction with the Islamic Conference) would be sponsored by the Muslim countries, and operate within these, with an endowment fund of $ 1,000 million and a projected annual income of around $60—$70 million. The Foundation will be non-political, purely scientific, and run by eminent men of science and technology from the Muslim world....The proportion of the endowment fund to be contributed by each sponsoring country will be a fixed fraction of the export earnings of the country. The 1972 schedule of export earnings is appended. In future years these earnings are expected to increase. However, even at the 1972 level of 25 billion dollars per year, a contribution of less than one percent per country per year would suffice to build up the initial endowment capital of one billion dollars over four years."

This proposal of Salam continues to be under the 'active consideration' of the governments of the Muslim countries. It appears that at the Taif Conference, 1981, a sum of 50 million dollars has been voted by the Muslim countries to realise the Foundation—fifty million is a far cry from the 1 billion Salam suggested which would have made it just the equal of the Ford Foundation.

On the 10th September 1974, Salam offered his resignation from Honorary Science Adviser, with the deepest sorrow and regret, to former Prime Minister, Mr. Z.A. Bhutto, stating as the principal reason:

"You are aware that I am a member of the Ahmadiyya Community in Islam. I believe that the recent decision of the National Assembly in respect of this Community is contradictory to the spirit of Islam because Islam does not give any segment of the Islamic Community the right to pronounce on the faith of any other segment, faith being a matter between man and his Creator".

Further elaborating on his resignation, Salam explained: "I cannot accept such a decision in any way whatsoever, and the only honourable thing left to do is to break away from the Government which has made such an amazing order."

Z.A. Bhutto accepted Salam's resignation, but asked him to keep giving advice on scientific matters on an informal basis. To this Salam agreed. One of his initiatives was the starting in 1976 of an (annual) International Seminar at Nathiagali in Pakistan's northern hills, co-sponsored by Pakistan's Atomic Energy Commission, the Trieste Centre and in the first year by the Swedish Development Authority SIDA.

In 1977, on his way to India to attend the hundred year international celebration of the great Indian physicist S.N. Bose whom Salam had known and greatly respected, Salam stopped at Karachi Airport and rang me up to see him. I was surprised to see that he had grown a beard and asked him the reason for this change. He replied: "You people have declared me outside the pale but you can't stop me from practising the *Sunna* and following the Holy Prophet."

When I asked how he felt on this decision of the Bhutto Government, Salam said: "Our *Ulemas* have throughout the ages made it a profession to call those Muslims who disagreed with them '*Kafirs*'. The Bhutto Government by enacting this into the constitution did a signal wrong to my birth right but even a bigger wrong to the nation by attempting to deprive the Muslim Ummah of a spokesman for science and technology. So far as the *Mullahs* are concerned I am in excellent company of Bu Ali Sina who was also declared a '*Kafir*' and who wrote:

کفر چو منی گزاف آسان نبود
محکم تر از ایمان من ایمان نبود
در دهر چو من یکی و آنهم کافر
پس در همه دهر یک مسلمان نبود

If you accuse me of being a *Kafir* this is not a simple matter
There is no faith stronger than my faith (*in Islam*)
I am unique in the world, and even this unique person you call a *Kafir*
If you call this unique person a *Kafir*,
then there is no Muslim left in the whole world".

Salam — The Scientist - Sage of the Developing World

According to Dr. Vannevar Bush, Scientific Adviser to President Roosevelt during the second world war, men of science, in western culture, have become the successors to the sages of the past for answers to all questions — questions which may have nothing to do with their own special disciplines — simply because scientists are considered to be analytical and objective, cultured in the scientific spirit which is cool and critical.

This is the role of the scientist-sage, the role Dr. Bush had talked about, which Salam has played and is playing to awaken the intellect in the developing world. It is true that there are advantages and disadvantages in possessing an emotional national allegiance to a country other than the one where one builds one's career, but Salam's career was equally built in two countries — one developing and the other a developed one. This produced in Salam a person of well-rounded world culture, not merely a scientist with one part of his brain over-developed.

He has turned out to be a remarkable man not only for something he can take out of his pocket and exhibit as a reward for his scientific knowledge, but for being something,

something recognizable for a man of deep intellectual breeding, whose trained judgement helps him to choose the right and reject the wrong.

So as a scientist-sage of the developing world, Salam has not replaced God with science but has tried to harmonise science with the cultural and religious values of the developing countries emphasising that "there is nothing more destructive of morale than economic inequality."

Before Salam, it was J.D. Bernal, a physicist called affectionately by his friends 'Sage' because of his breadth of intellect, who wrote in his "History of Science" that it was Ibn Khaldun who prefaced his treatise on history with a theory of economically determined social development, thus foreshadowing Vico and Marx.

Bernal wrote that religion, literature, and the arts are human activities concerned with the communication of ideas, images and feelings, which taken together contribute to the culture of society and assure its vitality and development.

Salam, concentrating on the development of productive forces to ensure society's vitality and development, drew its essence by writing that "the difference between two cultures (of the developed and the under-developed worlds) spring from a common cause — excess of science in one case and the lack of science in the other".

During his long period of exile in Europe, Salam has directed a part of his activities and thought to the evolution of developing societies and has written constantly about the laws of industrial development to reduce economic inequalities between the developing, the Muslim in particular, and the western societies. He feels that the religious leaders, the sages of the past, in the Muslim countries are too content with explaining the Islamic religion without any reference to science and its application.

As a scientist-sage, Salam took it to be his mandate in 1957 to create research teams and research institutes in all fields of national endeavour. And to fulfil the needs of Pakistan's universities, he emphasized the training of scientists in the great institutions of the world, mathematicians, physicists and agriculturists. He conceived an international centre

as a place where men from all countries could work alongside some of the most distinguished minds of physics.

Even the sages of the west tried to learn from him as Dag Hammerskjold, the Secretary General of the United Nations, recognized in 1962 that "it was important to establish an indigenous scientific community in developing countries for research and development." He said that it was needed to achieve an awareness of the significant development of world science and technology, an awareness which would enable a country to select and ensure the effective assimilation of technology which its economic and social objectives required. But then Salam had already identified the major hurdle when he quoted Rostow to emphasise "the need for the emergence to political power of a group, prepared to regard the modernization of the economy as a serious high-order political business".

As a representative sage of the developing world Salam spoke, in 1975, on 'Ideals and Realities' in the first lecture of the series on 'Human Global and Universal Problems' to students of the University of Stockholm, Sweden — a most civilized country as regards global issues. In this lecture he talked mainly of the exploitation of the developing countries by the advanced nations. Piling facts upon facts, he then quoted Omar Khayyam:

"Ah love! Could thou and I with fate conspire.
To grasp the sorry scheme of things entire,
Would not we shatter it to bits — and then
Remould it nearer to the heart's desire".

Salam declared: "The short-term crisis the world faces is simply this. The developing world — some nine-tenths of humanity — is bankrupt. We — the poor — owe the rich-one tenth of makind — some fifty billion dollars. We collectively need ten billion dollars to import ten billion tons of cereals every year to feed ourselves. My own country, Pakistan, owes some six billion dollars (eight billion in 1980) — roughly equal to Pakistan's GNP for one year, roughly equal to Pakistan's six years export earnings. In 1970, the world's richest one billion earned an income of $3,000 per person per year; the world's poorest one billion,

no more than a $100 each. And the awful part of it is that there is absolutely nothing in sight — no mechanism whatsoever — which can stop this disparity.

Development on the traditional pattern — the market economics — is expected to increase the one hundred dollar per capita of the poor to all of one hundred and three dollars by 1980, while the $3,000 earned by the rich will grow to $4,000 — and that is an increase of $3 against $1,000 over an entire decade. This is a system which in the last twenty years created liquidity and credits of 120 billion dollars allocating just five percent of these to the poor nations. This is the system which pays 200 billion dollars for world commodities, but only one sixth of this reaches the primary producer himself — the rest, five-sixths, going to the distributor and the middleman in rich countries — this is the system which gave seven billion dollars of aid last year and took away almost exactly the same from the poor in depressed commodity prices.... And when we did build up manufacturing industries with expensively imported machinery — for example, cotton cloth — stiff tariff barriers were raised against these imports from United States. With our cheaper labour, we were accused of unfair practices!

To give you an idea of these tariffs — suppose Pakistan exported cotton seeds, these would attract only $100 a ton as tariff. But woe-betide if the seed was crushed into oil. The oil fell into the category of manufactures, and the tariff shot up to $600 to be paid by Pakistan for discouraging it to export this simple 'manufacture'!

We were to be markets for steel, for machinery, for fertilizer, for armaments, we must not export anything remotely resembling manufacture.

Our indigenous science and technology — or indeed of any technological manpower development — there was neither need, nor appreciation, nor any role for it. Any technology we needed, we bought. It came hedged with all types of restrictions.... In the early 1950's, I looked upon my future as contributing to Pakistan's advance to technology and development as non-existent. I could help my country in only one way — as a good teacher — and that was to produce more physicists, who for lack of any industry, would in their

turn become teachers themselves, or leave the country. I knew that all alone, I had no hope of changing Pakistan's policies, so far as valuing science and techonology were concerned."

Salam served as a scientific secretary at the first 'Atoms for Peace Conference' convened by the UNO in Geneva, Seitzerland in 1955. He got involved with the United Nations again in 1962 when Dag Hammarskjold projected a UN Conference on Science and Technology for 1963. Referring to the Conference Salam commented in his paper "Ideals and Realities": "There appears to be no desire on the part of the industrialised countries to share technology with developing world except through the existing system of licensing, operating in the manner I have described earlier in the context of Pakistan. The net legacy of this Conference was the creation of an 18-man Advisory Committee on Science and Technology. We met for eleven years — twice a year; after eleven years labour, we have recommended yet another UN Conference on Science and Technology — to be held in 1978, this to meet and create the same science and technology development agency we proposed fifteen years ago. This time we are likely to get this because Dr. Kissinger gave the proposed Conference his blessing three weeks ago".

....In 1973 the world military expenditure came to 245 billion dollars. This sum is 163 times greater than that spent on international cooperation for peace and development through the United Nations system.

During the two decades, 1960s and 1970s, the total military expenditure was $4,000 billion, which is greater than all goods and services produced by all mankind in one year... About fifty million people are employed for military purposes in armed forces and defence activities. Close to half a million scientists and engineers, almost half of the world's scientific and technological manpower, is devoted to military research and development, costing between twenty to twenty-five billion dollars. These sums represent forty percent of all public and private research and development expenditure mankind appropriates."

"What the developing countries really want on a psychological plane is to regain their sense of dignity and self-respect

which they enjoyed for long centuries and which they lost only during the brief period of western domination; a domination based essentially on an industrial and technological revolution which is hardly two centuries old."

Talking on another occasion about 'Organized Research and Common Sense' Salam observed: "We do possess the information necessary to solve the problems of hunger and most diseases. We simply do not take the right political, economic and social decisions to put the requisite policies into effect and give the requisite technologies the scope they should have.

There is one field, however, where I should certainly wish to stop all research: armaments research. But I am pessimistic about the possibilities of zero-growth in this sector. There was once a proposal made in Cambridge, suggesting that the great physicists of the world (Oppenheimer, Dirac, Fermi) should forswear all research on programmes leading to the destruction of mankind. Dirac, who was present at the meeting, responded sagely: "You may persuade the first-rate scientists to do this, but never the second-raters — and that is enough to create all the new armaments".

Asked to answer a question: "Do public administrators have an adequate perception of the total force of science and technology in the life and culture of a nation", Salam responded: "The political administrator has no perception of this, by and large. Of the ninety-two countries we deal with here in Trieste perhaps half a dozen are blessed with a leadership possessing such perception. Political leaders know that science and technology can 'work miracles', but they think of scientists and engineers as sequested specialists who can render particular services when called upon to do so — like the specialist *chef* who works in a household which he does not manage. Too often (especially in the developing world) the politicians have been grounded in the classics, history, law (but very seldom in business and administration) so they tend to look at scientifically trained persons as social know-nothing. It is this class of civil servant or administrator or politician who goes out in search of funds for a technical project, the source of which is often a major foreign power or the United Nations Development Programme. Together

with the money he seeks foreign know-how, importing the specialized manpower needed to staff the technical scheme in preference to turning to his own weakly organised, immature scientific manpower. The vicious circle continues. The indigenous technologist remains immature because he is never called upon to shoulder any responsibility, administrative or technical, except in a very subordinate capacity." Salam's solution is that scientifically-trained specialists must collaborate more and more with economic planners — if economists can give up their omnivorous arrogance. Scientists and technologists have to be provided opportunities to develop both a broad vision and a strong social conscience but it is the technologically illiterate civil servants in the developing world who encourage the abuses like importing of foreign technical skills in preference to building up a local talent.

In his address to UNESCO Celebration of the Centenary of Einstein's Birth on 9 May 1979, in Paris, Salam made a strong case to support the survival of the scientists from the developing world by highlighting the impediments Einstein faced for his commitment to science. Salam wrote: "There has been no one like Einstein in this Century; perhaps never in the whole history of human thought, so far as physical sciences are concerned. Certainly there never has been anyone so singly responsible for so much revolutionary thinking in Physics. But how easily may Einstein have been lost, particularly if he had been born in a developing country. At the age of fifteen he was summoned by one of his teachers at the Luitpold Gymnasium in Munich; the teacher expressed the wish that Einstein leave the school. In Einstein's words: "To my remark that I had done nothing amiss", he replied only, "Your mere presence spoils the respect of the class for me". This was a reference to Einsteins's independence. At the age of sixteen and a half, Einstein wished to enter the Zurich Polytechnic. He took the Entrance Examination for Engineering and, fortunately for Physics, he failed. A year later, he succeeded, but by now he had given up all thought of becoming an engineer. Einstein graduated from the Zurich Polytechnic in the year 1900; he sought university positions, but failed "for I was not in the good graces of my former teachers." He maintained himself by finding temporary

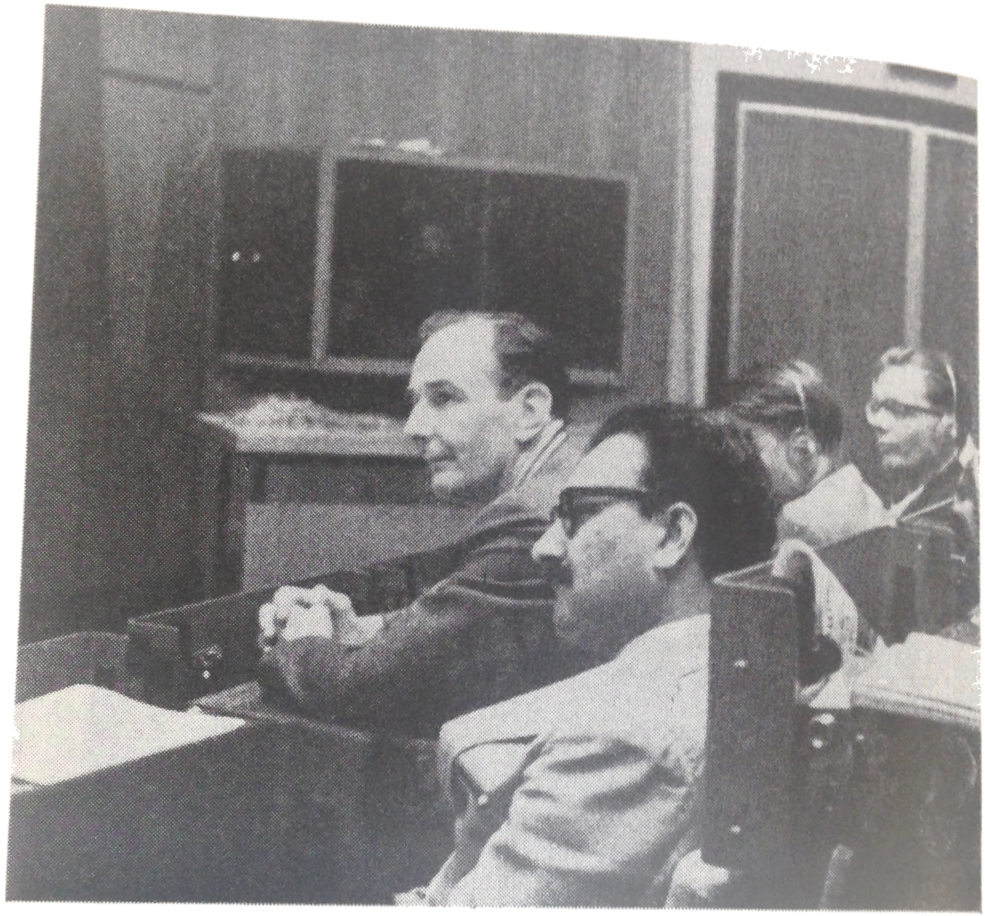
jobs, performing calculations, private tutoring at 3 francs an hour, and school teaching.

In November 1901 be submitted a research paper as a thesis for a doctoral degree — a necessary passport for university teaching. Although this paper—his second — was accepted by the prestigous journal, *Annalen der Physik*, the University of Zurich rejected it as inadequate for a Ph.D. According to Banesh Hoffmann, Einstein felt himself sinking hopelessly in the quagmire of a world that had no place for him. A poignant episode during 1901 will illustrate what I mean. In 1901 Einstein's first research paper had been published in *Annalen der Physik*. Einstein sent a copy of this to Prof. Wilhelm Ostwald—later a Nobel Laureate — with the letter: "Since I was inspired by your book on general chemistry....I am taking the liberty of sending you a copy of my paper. I venture also to ask you whether perhaps you might have use for a mathematical physicist....I am taking the liberty of making such a request only because I am without means..."

In spite of a second reminder there was no response from Ostwald, nor from Prof. Kamerlingh-Onnes in Laiden to whom Einstein sent a similar letter.

At this stage, in Banesh Hoffmann's words, a beautiful event occurred in Einstein's life of which he knew nothing. His father, an unsuccessful merchant, in ill health, and a stranger to the academic community, took it upon himself to write to Prof. Ostwald. Here is his letter: "I beg to you to excuse a father who dares to approach you, dear Prof. in the interest of his son....My son Albert Einstein is 22 years old... Everybody who is able to judge praises his talent....My son is profoundly unhappy about his present joblessness, and every day the idea becomes more firmly implanted in his mind that he is a failure in his career and will not be able to find the way back again....Because, dear Prof. my son honours and reveres you .... I permit myself to apply to you with the plea that you read his article..and hopefully that you will write him a few lines of encouragement so that he may regain his joy in life and his work....My son has no idea of this extraordinary step of mine."

PROFESSOR ABDUS SALAM IN PEOPLES REPUBLIC OF CHINA WITH PREMIER CHOU EN LAI



PROFESSOR ABDUS SALAM ALONG WITH PROFESSOR P.T. MATTHEWS ATTENDING AN INTERNATIONAL CONFERENCE IN HIGH ENERGY PHYSICS.

INSTITUT INTERNATIONAL DE PHYSIQUE SOLVAY

CINQUIEME CONSEIL DE PHYSIQUE — BRUXELLES, 1927

A. PICCARD   E. HENRIOT   P. EHRENFEST   Ed. HERZEN   Th. DE DONDER   E. SCHRODINGER
E. VERSCHAFFELT   W. PAULI   W. HEISENBERG   R.H. FOWLER   L. BRILLOUIN   P. DEBYE
M. KNUDSEN   W.L. BRAGG   H.A. KRAMERS   P.A.M. DIRAC   A.H. COMPTON   L. de BROGLIE
M. BORN   N. BOHR   I. LANGMUIR   M. PLANCK   Mme CURIE   H.A. LORENTZ   A. EINSTEIN
P. LANGEVIN   Ch.E. GUYE   C.T.R. WILSON   O.W. RICHARDSON
Absents : Sir W.H. BRAGG, H. DESLANDRES et E. VAN AUBEL

INSTITUT INTERNATIONAL DE PHYSIQUE SOLVAY

SIXIEME CONSEIL DE PHYSIQUE — BRUXELLES, 20-26 OCTOBRE 1930

A. PICCARD W. GERLACH C. DARWIN P.A. DIRAC E. HENRIOT MANNEBACK H.A. KRAMERS
J.H. VAN VLECK W. HEISENBERG E. HERZEN J. VERSCHAFFELT A. COTTON J. ERRERA O. STERN
H. BAUER P. KAPITZA L. BRILLOUIN P. DEBYE W. PAULI J. DORFMAN E. FERMI
Th. DE DONDER P. ZEEMAN P. WEISS A. SOMMERFELD Mme CURIE P. LANGEVIN A. EINSTEIN
O. RICHARDSON B. CABRERA N. BOHR W. J. DE HAAS
Absent: Ch.E. GUYE et M. KNUDSEN

There was still no reply. Eventually as is well known, in 1902 Einstein did find a job at the Swiss Patent Office — first as Probationary Technical Expert, third class and then with a promotion to Engineer, second class. It was here far from adequate scientific libraries, far from the stimulating research atmosphere of a conventional university physics department, snatching precious morsels of time for his own surreptitious calculation, which he guiltily hid in a drawer when footsteps approached, Einstein produced his revolutionary papers on quantum theory of light and the unification of space and time, during 1905. And during all this time, he was without the precious Ph.D.

"I shall not become a Ph.D....the whole comedy become a bore to me". Thus wrote Einstein, for a second attempt at this degree made in 1905 had also failed. A third attempt did eventually succeed, but by then he did not need the Ph.D. any more for he had already become famous.

I have told this story in detail; for the simple reason that every one of the discouragements he suffered from are a norm for a scientist in a developing country. And even in a developed country today, would an Einstein, with his commitment to science for its own sake, fare any better"?

Addressing the Board of Governors of the IAEA in 1980 on the celebration of the award of the Nobel Prize in Physics given to him in 1979, Salam chose to speak on "Internationalization of Science in Developing Countries".

Salam said: "In sciences, as in other spheres, this world of ours is divided between the Rich and the Poor. The richer half—the industrial North and the centrally managed part of humanity—with an income of five trillion dollars, spends two percent of this—some hundred billion dollars—on non-military science and development research. The remaining half of mankind—the poorer south, with one fifth of the income (one trillion dollars)—spends no more than two billions on science and technology. On the percentage norms of the richer countries, they should be spending ten times more—some twenty billions.

At the United Nations-run Vienna Conference on Science and Technology six weeks ago the poorer nations pleaded for international funds to increase the two billions to four billions.

They obtained promises, not of two billions, not of one billion, but only one seventh of this."

Maintaining his sense of dignity and self respect, Salam declared that the history of science, like the history of all civilizations, has gone through cycles, as in the march of science and civilization other cultures, other lands have played their humble roles. Referring to George Sarton's five-volume History of Science, he explains quantitatively that the story of achievement in sciences had been divided into ages, each age lasting half a century. With each age Sarton had associated one central figure.

"Thus 450 BC—400 BC Sarton calls the Age of Plato; this is followed by half centuries of Aristotle, of Euclid of Archimedes and so on. From 600 AD to 650 AD is the Chinese half century of Hsiun Tsang, from 650 to 700 AD that of I-Ching, and then from 750 AD to 1100 AD—350 years continuously—it is the unbroken succession of the Ages of Jahir, Khawarizmi, Omar Khayam—the Arabs, Turks, Afghans and Persians—men belonging to the culture of Islam. After 1100 appear the first western names, Gerard of Cremona, Roger Bacon, Jacob Anatoli—but the honours are still shared with the names of the Spanish Ibn-Rushd (Averroes), with Tusi and Ibn-Nafis—the men who anticipated Harvey's theory of circulation of blood...After 1350 however, the developing world loses out except for the occasional flash of scientific brilliance, like that at the Court of Ulugh Beg—the grandson of Timurlane, in Samarkand around 1400 AD; or of Maharaja Jai Singh of Jaipur in 1720—who corrected the serious errors of the then western tables of eclipses of the sun and the moon by as much as six minutes of arc. As it was, Jai Singh's techniques were surpassed soon after with the development of the telescope in Europe."

Starting with this reference point in the world of physics, the eastern names are V.C. Raman—the Nobel Prize 1930, Hideki Yukawa—Nobel Prize 1949, Lee and Yang—Nobel Prize 1957, Leo Esaki—Nobel Prize 1973, Samuel Ting—Nobel Prize 1976 and Abdus Salam—Nobel Prize 1979. (Parenthetically one may note that only Salam has the nationality of a developing country of the Prize Winners who are living. Others like Lee and Yang and Ting are U.S. nationals.

According to A. H. Compton (Nobel Prize in Physics 1927) during Harun-ul-Rashid's time (800 AD) astronomy, algebra, chemistry, optics and medicine developed and flourished in Muslim lands. Its foundation was laid by the Muslims on translations from Greek literature. At that time the west acknowledged that Muslims held the learning and science of the period and craved for their intellectual treasures while hating and fearing the Muslim religion.

Compton observed that then the Muslims got worried about science because one of the primary tenets of Islam is the supremacy of God—and this had ultimately led to the belief that "Whatever may happen, in the end everything has to come out according to the will of God." So the religious leaders started fearing the study of science because for them it meant encouraging disbelief—just as the Marxists feared the study of Quantum Mechanics for a very short period, as it violated their materialist view of mechanical determinism and Newtonian law of causality.

As against this Salam, so far as Muslims are concerned, had argued that in contrast to 250 verses of the Holy Book which are legislative, 750 verses—almost one eighth of the Holy Book—urge the believers to study Nature—reflect—*al-taffakur*—and make the scientific enterprise an integral part of the Community's life. Likewise the Holy Book mentions *Al-taskhir*—subjection of nature, again and again as one of the attributes of Allah, which the believer is urged to cultivate through technology. At the same time by connecting the 'cycles-of-history' to the achievements in science, Salam has discarded the broadly held view of the western world that science could not progress in Muslim lands since Imam Ghizali issued a decree that "Science leads to loss of belief in God and in the origin of the Universe".

In his address to IAEA Salam continued: "Now, in this context the question we must ponder is this: are the developing countries today on the road to a renaissance in sciences—as the west was in the 13th century at the time of Michael the Scot? Unfortunately the answer is No.

There are two prerequisites to this renaissance: one, availability of places like Toledo and Salerno for international concourses, where one can light a candle from a candle.

Second, the interest in our own developing societies to give the topmost priority to firstly, the acquisition of knowledge and secondly, its dissemination throughout the community. This is what was done, for example, by the Japanese Constitution after the Meiji Revolution.

Regarding the first point, regretfully, the opportunities for international scientific concourses are fast shrinking, with greater and greater restrictions in the traditional countries like the UK and USA's acceptance of overseas scholars, including those from developing countries. When I was a student at Cambridge, the fees amounted to no more than Pounds 70 a year; next year they will be three thousand and five hundred Pounds, an increase by a factor of fifty. As I will discuss later, it is becoming increasingly clear that the developing world will need internationally run—United Nations agency run post-graduate universities of science—not just for research, but also for the high level teaching of modern technology and sciences, both pure and applied.

The second prerequisite for development of science and technology is a passionate, consuming desire on the part of the developing countries and the removal of all internal barriers in its acquiring dissemination of sciences and technology throughout their societies and finally, the application of these towards development. Unfortunately, and I say this with anguish, the prognosis in this respect is not very bright.

Salam continued: "I would like to conclude with three appeals.

My first appeal is to the developing countries. In the end, science and technology among them is their own responsibility. Speaking as one of them, let me say this: Your men of science are a precious asset. Prize them, give them opportunities, responsibilities for scientific and technological development of their own countries. At present even the small numbers that exist, are underutilized. However, the goal must remain to increase their numbers tenfold, to increase the 2 billions internally spent on science and technology to 20 billions. Science is not cheap; and in addition, we must not forget that technology in the conditions of today, cannot, in the long-run, flourish without science flourishing at the same time. This was dramatically emphasised recently to me by a Turkish physicist from

the University of Samsun who recalled that Sultan Salim III did introduce studies of algebra, trignometry, mechanics, ballistics and metallurgy in Turkey already as long ago as 1799, creating special schools for these disciplines with French and Swedish teachers. His purpose was to modernize the army and rival European advances in gun-foundaries. Since there was no corresponding emphasis on research in these subjects and since the scholarly establishment in the medresas who called themselves scientists, *alims*, had nothing but contempt for these new technological schools—"funun"—Turkey did not succeed. In the long run, in the conditions of today, technology unsupported by science, simply cannot flourish.

My second appeal is to the international community—both of Governments and of my fellow scientists, as well as the United Nations agencies.

A world so divided between the haves and have nots of science and technology cannot endure; at present an International Centre for Theoretical Physics (with a budge of 1.8 millions) is all that is internationally available for physics for 90 developing countries. Compare this with European joint projects involving physics alone, of 1/2 billion dollars annually. Compare this with the cost of one nuclear submarine; 1.7 billion dollars. One thousand centres like Trieste could flourish for one year, for one of these and at present there are two hundred and fifty nuclear submarines in the world's oceans. Somehow, somewhere a break must come.

And finally, and in all humility, I wish to make an appeal to the Governors here today from the OPEC countries. The President of Venezuela was in Vienna on 14 February. Addressing an OPEC staff meeting, he spoke of the need for an OPEC international centre for sciences. I would like to address myself in this context, particularly to my brothers from the OPEC Islamic countries. To some of you Allah has given a bounty—an income of the order of 100 billion dollars. On the international norms these countries should be spending 1 billion to two billions of dollars annually in supporting science and technology. It is your forebears who were the great torchbearers of international scientific research in the 8th, 9th, 10th and 11th centuries. It was these forebears who funded the first *Bait-ul-Himas*—Advanced Institutes for Sciences—

where concourses of scholars from Arabia, Iran, India, Turkey and the Byzantium congregated. Be generous once again. It is as much our responsibility in accordance with Allah's injunctions, to add to human knowledge as was theirs in their day. Spend the billion dollars on international science, even if others do not. Create a fund—available to all Islamic, Arab and developing countries, so that no potential, high-level talented scientist in the developing world is wasted. My humble personal contribution to this fund has been all I possess—the $ 60,000 the Nobel Foundation so generously awarded me."

Abdus Salam, servant of peace, is a doctor honoris causa of Eleven Universities, was honoured by about twenty distinguished awards, has been elected fellow or member of more than twenty prominent societies of the world and has three daughters and two sons. Probably he is the most learned, highly distinguished and the best equipped intellect capable to guide and direct the Muslim people to intellectual, scientific and economic renaissance through the promotion of science and technology in Muslim lands. Probably Salam is determined to turn the 'cycle-of-history' in favour of developing countries—to make them contribute significantly in the achievements of science and technology in the twentieth century!

To sum up, what one learns from Salam and his life as regards the development of renaissance in science in Muslim and developing lands for building up a self-reinforcing economic growth is to acquire the two pre-requisites of skill and capital, where capital should come, mainly, from savings and skills should be developed by assigning top-priority to the acquisition of knowledge coupled with research; and its dissemination throughout the society—by learning historical lessons, at least, from the experiences of Britain, Japan, USSR and Peoples Republic of China. The information necessary to solve the problems of hunger and most diseases is available, but what is lacking is the emergence to political power of a group with an inspired leadership prepared to regard the development of renaissance in science and the modernisation of the economy as a serious high order political business by taking the right political, economic, social, educational and scientific decisions to put the requisite policies into effect and give the requisite technologies the scope they should have—as

the "difference between two cultures spring from a common cause—excess of science in one case and the lack of science in the other"!

Scientific Contributions of Muslims in History*

Intellectual and scientific activity flurished among Muslims during the Abasaid period (750—1000)—the period Baghdad had grown from insignificance to a world centre of fabulous wealth and international diplomacy. To emphasise how comparatively well paid the scientific career was at that time, it is reported that Jibril ibn-Baktishu, the court physician of Harun al-Rashid and al-Ma'mun, made a fortune of nine crore dirhams. As private physician of the Caliph he received a salary of one hundred thousand dirhams for bleeding the Caliph twice a year and an equal amount for administering a six monthly purgative draught. During this period the industry also flourished as many looms of Iran and Iraq turned out carpets and textiles of a very high quality. A Caliph's mother purchased a carpet specially designed for her at a price of thirteen crore of dirhams, the carpet containing figures of all kinds of birds knitted in gold and their eyes made from rubies and other precious stones. This scale of luxurious living made the period a legend in history and in fiction, but what has rendered this Muslim period especially prominent in world civilization is the fact that it developed the most progressive intellectual awakening in the history of Muslims after the Holy

* Mainly relied on Professor Haities book "History of the Arabs"

Prophet (peace be upon him), and one of the most significant in the whole story of world thought and culture. This awakening had its initial share in a large measure to foreign contacts and their influences and was accelerated by translations into Arabic from Greek, Persian, Syrian and Sanskrit. Starting hardly with any science, philosophy or literature of their own, the Muslims armoured with a keen sense of intellectual curiosity and an appetite for learning soon became the heir and beneficiary of the older and more cultured peoples whom they encountered and conquered.

After the establishment of Baghdad as the capital, the Muslim scholars, in only a few decades, assimilated all that had taken the Greeks, Persians and Indians to develop upto that period. The Muslims were soon in possession of the chief philosophical works of Aristotle, Plato and his leading commentators, and of the most of the medical writings of Galen and other famous physicians of foreign civilizations. The culmination of Greek, Persian and Indian influences was reached during al-Ma'mun's reign (813-832) as he had rationalistic tendencies based on the philosophy that religious texts must accommodate the judgements of reason. This principle led him to seek justification for his views in the philosophical works of the Greeks. He believed that there was no real difference between reason and religious law and acted accordingly, in pursuance of his belief, to establish in 830 in Baghdad his famous '*Bayt-ul-Hikmah*' (house of wisdom), a combination of a great library, an academy and a translation bureau which proved the most outstanding educational institution since the foundation of the Museum in Alexandria in the first half of the third century B.C. The Abbasid era of translation lasted about a century. In the case of many difficult passages in the original the translation was done word by word, and when no Arabic equivalent was available the Greek term was simply transliterated with some adoption. So by the tenth century Arabic, which in pre-Islamic period was only a language of poetry and after the Holy Prophet (peace be upon him) mainly a language of religion, had been developed in an unprecedented way into a concise medium containing scientific thought and philosophical ideas of the highest order.

However al-Ma'mun, whose rationalistic and philosophical interests had raised 'rationalism' to a state religion, issued in 827, according to some historians, a proclamation declaring the dogma of "the creation (Khalq) of the Koran", in opposition to the orthodox belief that in its actual form, in its Arabic language, the Koran is the identical reproduction of a Celestial original. In 833 the Caliph issued his intolerant decree that no *qādi* who did not subscribe to the views of the creation of the Koran could hold his office or be appointed to it. At the same time he initiated an inquisitorial court for the trial and conviction of those who differed with his belief. Thus by a fundamental contradiction he, the champion of rationalism and reason, turned intolerant and a suppressor of free-thought. However the age of translation and acquisition of knowledge (750-850) was followed by a period of creative activity. In medicine, philosophy, mathematics, chemistry, astronomy and geography the Muslims' independent work was significant as they carried on original thinking and scientific research. Abu-Bakr Muhammad ibn-Zakariya al Razi (865-925) was probably the most original of all the Muslim physicians. While still in Iran al Razi wrote a comprehensive book in ten volumes named "*Kitab al-Tibb al Mansuri*' of which a Latin translation was first published in Italy in the late fifteenth century. One of his established monograph is a treatise on measles and smallpox. In this monograph one finds the first clinical account of smallpox. His most important work, however, was 'al-Hawi' (the comprehensive book) which was first translated into Latin in 1279. Under the name 'Continens' it was repeatedly printed from 1486 onwards—a fifth edition appearing in Venice in 1542. This book sums up the knowledge the Muslims possessed at that time including the contributions of other non-Muslim societies. These medical works of al-Razi exerted a remarkable influence, for centuries, over the minds of the Latin Europe. Al Razī is also accepted as the inventor of the seton in surgery. He was also the first to term '*tibb ruhani*' (spiritual cure) corresponding to western 'psycho-therapy'.

One of his principal works on chemistry named '*Kitab al-Asrar*' (the book of secrets) was printed in many editions and was finally reproduced into Latin by the eminent western

translator Gerard of Cremona around 1187 and consequently became a major source of chemical knowledge in Europe. The most illustrious person in Muslim medical history after al-Razi is that of Ibn-Sina. As a young man he succeeded to cure the Sultan of Bukhara, Nuh ibn-Mansur (976-1097) and was therefore provided the opportunity of utilizing the Sultan's great library containing all the scientific literature available upto that time. Among his chief scientific books are the '*Kitab al-Shifa*' (book of healing), a philosophical encyclopaedia based upon the Aristotelian tradition as modified by Muslim thought and post-Platonic developments, and 'al Qanun fi al-Tibb,' which sums up the final codification of standard medical thought of the time. Al Qanun's translation into Latin was done by Gerard of Cremona in the twelfth century. This book got immediately accepted as a classical work in medical literature displacing the works of al Razi and Galen which was the Greek medical lore of that age. This book was also prescribed as the text for medical education in the schools of Europe and it served, from the twelfth to the seventeenth century, as the fundamental guide to medical science. It recognised the contagious nature, for the first time, of tuberculosis and the spreading of certain diseases by soil and water. It distinguished mediastinitis from pleurisy and puts forth a scientific diagnosis of ankylostomiasis and attributed it to an intestinal worm.

Ali ibn-Abbas al-Majusi put forth the concept of the capillary system and a proof that in the act of child-birth the baby does not come out by itself but is pushed out by the muscular contractions of the womb. Ibn-Rushd's chief contribution to medicine was his great work entitled 'al-Kulliyat fi al-Tibb' (generalities on medicine), in which it was mentioned that no one was taken twice with smallpox and the function of the retina was clearly explained by him.

Al Zahrawi living in the eleventh century was the greatest surgeon of the Muslims. He contributed new ideas of cauterization of wounds, crushing a stone inside a bladder and the necessity of vivisection and disection. His works were translated into Latin also by Gerard of Cremona and its various editions came out at Venice in 1497, at Basel in 1541 and at Oxford in 1778.

His books contained drawings of instruments which laid the foundations of surgery in Europe.

Ammar ibn-Ali al-Mawsib suggested a radical operation for soft cataract by suction through a hollow tube of his own design. Later on Khalifah Ibn-abu-al-Mahsin was so sure of his expertise as a surgeon that he removed successfully a cataract for a one-eyed man without any reluctance. Ali ibn-al-Nafis contributed a clear concept of the pulmonary circulation of the blood, three centuries before the Portuguese Servetus who is credited with the discovery in the west.

With the objective to determine the circumference of the earth Al-Ma'mun's astronomers performed one of the most sophisticated geodetic operations—the measurement of the length of a terrestrial degree. This measurement was done on the plain of Sinjar north of the Euphrates. It yielded 56.667 miles as the length of a degree of the meridian—a remarkably accurate measurement, exceeding the real length of the degree at that place by about 2,877 feet.

Al-Battani (877-918) was an original research scientist who made many corrections to Ptolemy and improved the calculations for the orbits of the moon and certain other planets. He showed the possibility of ring-shaped eclipses of the sun and presented original theories on the determination of the visibility of the new moon. He also popularized the first concepts of trigonometry, algebra and analytical geometry.

Al-Biruni (973-1048) is considered the most original and profound scientist among Muslims in the field of Astronomy. He discussed with great perception the then controversial theory of the earth's rotation on its axis and accurately determined the latitudes and longitudes. With almost complete accuracy he determined also the specific gravity of eighteen precious stones and metals. The researches of al-Khayyam and his collaborators produced a calender which is even more accurate than the Gregorian calender—the calender that yields an error of one day in 3,330 years whereas al-Khayyam's introduces an error of one day in about 5,000 years. Al-Khwarizmi was the towering personality in the early history of mathematics. He compiled the oldest astronomical tables and composed the oldest works on arithmetic and algebra. His book '*Hisab al-Jabr-w-al-Maqabalah*' (the calculation of integration and

equation) presented over eight hundred examples and was considered his major work. It was translated in the twelfth century into Latin by Gerard of Cremona and was used until the sixteenth century as the principal mathematical text of European universities, serving to introduce the science of algebra in Europe. Al-Khwarizmi's works were also the main source for the introduction of the Arabic numerals, called algorisms after him, into Europe. Among the later mathematicians was Umar al-Khayyam who produced geometric and algebraic solutions of equations of the second degree and an excellent classification of equations.

The muslims also contributed singificantly in the kanowledge of chemistry. They introduced the objective experiment, an obvious advancement over the confused speculation of the Greeks. Muslim chemists were accurate in the observation of phenomen on and industrious in the accumulation of facts, though weak to draw scientific conclusions and suggest a final theory. The father of muslim chemistry was Jabir ibn-Hayyan who lived in the eighth century. He clearly recognised and stated the significance of experimentation and made important contributions in both the theory and practice of chemistry. He improved on the methods for evaporation, sublimation, melting and crystallization and described scientifically the two principal operations of chemistry; calcination and reduction.

The first Muslim scientist in the field of zoological and anthropological sciences was Al-Jahiz in the nineth century. His works, in which he also cites Aristotle, contains hints of later theories of adaptation, evolution and animal psychology.

Ikhwan al Safa, in the tenth century, worked out a theory of cosmic cycles by which cultivated lands turn desert, desert land become cultivated, steppes change into seas and seas become steppes or mountains. Yaqut ibn-Abdullah al-Hamawi in the twelfth century compiled a geographical dictionary in which names of places were alphabetically arranged. It was a genuine encyclopaedia containing the whole fund of geographical knowledge of the age, and listing valuable information on history, ethnography and natural science. Abd-al-Rahman ibn-Khaldun (1332-1406) attempted to formulate laws of national progress and decay, and discovered

the true scope and nature of history. He is acknowledged to be the real founder of the science of sociology. No Muslim or European had ever taken a view of history at once so comprehensive and philosophical as that taken by Ibn-Khaldun.

The greatest names in the field of early Muslim philosopby were of al Kindi, al Farabi and ibn-Sina. Al-Kindi (870-950) worked in Neo-Platonic fashion to combine the views of Plato and Aristotle and considered the Pythagorean mathematics as the foundation of all science. His main work on physiological and geometrical optics was widely studied in both Muslim and European lands until superseded by the superior works of in-al-Haytham. Ibn-al-Haytham, born about 965 contradicted the theory of Euclid and Ptolemy that eye sends out visual rays to the object of sight. He performed experiments for testing the angles of incidence and reflection. In certain experiments he suggested the theoretical discovery of magnifying lenses which was actually made in Italy three centuries later.

The harmonization of Greek philosophy with Islamic thought started by al-Kindi was continued by al-Farabi. Probably inspired by Plato's Republic and 'Aristotle's Politics,' al-Farabi described his concept of a model city similar to a hierarchical organism, comparing it with the human body where the seat of authority, the sovereign, corresponding to the heart, is fed and served by functionaries who are themselves supported and sustained by others still down the line. In his ideal city the object of association and collective living was the happiness and well-being of its citizens, and the qualification for the selection of the sovereign was that he should be perfect both intellectually and morally — *probably a necessary condition to implement and practise a perfect code of life in society.* It was, however, ibn-Sina who placed in the eleventh century the sum total of Greek wisdom at the service of the educated Muslim in a simple intelligible form. Through him the Greek system was rendered suitable for incorporation in Islamic thought.

Philosophy, to the Muslims, was a knowledge of the true cause of things as they really are, in so far as it is possible to confirm them by human faculties. The

'Mutazilah-philosophy' developed a rationalist wing which accorded the products of human reason an absolute value and Caliph al-Ma'mun lent official belessings to this school of thought. Among the leaders of the Mu'tazilite school was al-Nazzam who proclaimed that doubt was the first absolute requirement of knowledge. The man credited with refuting the Mu'tazilite philosophy and re-establishing the orthodox view which has since become the heritage of Sunni Muslims was abu-al-Hasan Ali al-Ash'ari in the tenth century. It is also attributed to him that he introduced the concept 'bila kayf' (without modality) according to which a Muslim is expected to accept the allegorical expressions in the Koran without any explanation given or demanded. This principle seemed to have served, according to some thinkers, as a depressive influence on scientific research and free thought. Al-Ash'ari was succeeded by al-Ghazzali who was born in 1051 and died in 1111. Through him orthodox conjectures and derivations reached their highest level. His works deposed fiqh from the high position it had possessed, employed Greek dialectic to establish a pragmatic system and made philosophy acceptable to the orthodox school of Muslims. It is to the everlasting brilliance of al-Ghazzali that he reconciled the two views of thought, the Greek plilosophy and the monotheistic religion, and passed them on harmonized into Europe. In his approach al-Ghazzali seemed to have succeeded in reconciling faith and reason, and science with religion. To him Aristotle was truth, Plato was truth, the KORAN was truth; but truth must be one. So there arose the necessity of harmonizing the three, and in this task al-Ghazzali succeeded in his time.

Partly translated into Latin before 1150, al-Ghazzali's writings affected significantly the Christian and Jewish scholastic thought as Thomas Aquinas and Pascal were considerably influenced by his ideas which came closest to orthodox Christian views. According to Professor Hitti, "the scholastic shell constructed by al-Ghazzali has held Islam to the present day, but Christians succeeded in breaking through its scholasticism, particularly at the time of the Protestant Revolt. Since then the West and the East have parted company, the former progressing in science while the later stood still."

Ibn-Bajjah in the twelfth century tried to teach that the gradual perfection of the human spirit through union with the "Active Intellect" is the object of philosophy. Ibn-Tufayl introduced the concept that human capacity unassisted by external agency may acquire the knowledge of the higher world and may feel by degrees its dependence upon a Supreme Being. The greatest moslem philosopher was probably ibn-Rushd who lived from 1126 to 1198. His most significant writing was his 'Tahafut al-Tahafut' (the incoherence of the incoherence), a reply to al-Ghazzali's attack on rationalism in his book named 'Tahafut al-Falasifah' (the incoherence of the philosophers). It was this work that made ibn-Rushd famous in Europe. To Europe he became 'the Commentator" as Aristotle was called "the teacher". From the end of the twelfth to the end of the sixteenth century Ibn-Rushd's philosophy remained the dominant school of thought in Europe inspite of creating hostile reactions among the muslims as well as the christian ministers. He was a rationalist and claimed a muslim's right to submit everything save 'the revealed dogmas of faith' to the judgement of reason, now called science. For him the freedom of expression and freedom of speech were perfect Islamic concepts as for him a muslim society was a free society of free men, free to speak, think, act, feel, own, regulate a society, for the good of all, in which every man would have a chance to grow, and those whose chances were lesser would be protected rather than exploited by those in power — a fundamental philosophy of the free-world in the twentieth century. Ibn-Rushd was not, in any way, a free-thinker or an unbeliever. After being censored and purged of 'objectionable material' by church authorities, his philosophical writings became prescribed studies in the universities of Paris and other institutes of high learning. With all the misconceptions compiled under its name, the intellectual and rationalistic movement energized by ibn-Rushd flourished as a living force in European thought until the birth of modern experimental science as a guiding principle. This movement of ibn-Rushd failed somehow to strike roots in muslim lands.

In the process of passing on this scientific and philosophical knowledge of muslims into Europe, Toledo in Spain, maintaining its position of an important seat of muslim learning

even after its Christian conquest in 1085, acted as the main channel. By the end of the thirteenth century Muslim science and philosophy had been assimilated by Europe; and Spain's function as an intermediary came to an end. Then as science developed and flourished in Europe from the fourteenth century onward, Spain's link for Muslims got severed and their contribution became negligible over the next seven centuries, till the middle of the twentieth century when Salam came on the scene.

With this rudimentary sweep on the history of the scientific development in the world, one has to fathom and assess the significance and the magnitude of the scientific achievements of Salam and the role that he has played and is playing in the service of science in Pakistan and other developing lands. Salam has, in brief, not only assimilated the major works created and developed in mathematics and physics for the last eight centuries in the west but has also made original contributions in mathematical physics which qualified him to win the Nobel-Prize for Physics in 1979. After a gap of seven centuries his two books on symmetries have become a part of prescsibed studies in post-graduate physics schools in Europe and the United States. As regards his philosophical thoughts as a scentific thinker he declares that science must be kept completely separate from religion, and as poverty is a form of 'Kufr' for him, he preaches the development of science and technology in Muslim lands as an initial and major part of Jihad under the exsisting conditions. To him new developments in science produce new insights and higher understanding of religion as true religion is strengthened rather than is weakned by the advancement of true science. To me Salam is more close to ibn-Rushd than to al-Ghazzali in religious philosophical thought in the 20th century.

PART — II

Hafiz Abdul Majid's letter, dated 13-8-42 to Chaudhary Muhammad Hussain.

Qinkar Lodge
Simla E
13-8-42

محترمی محمد حسین صاحب—سلام مسنون

آپ نے جو خط میاں افضل حسین صاحب کو ۱۳-۷-۴۲ء کو بھیجا تھا وہ انہوں نے مجھے بھیج دیا ہے۔ ان کا خیال تھا کہ ضروری مشورہ میں آپ کو دے دوں۔ جواب میں تاخیر کی وجہ یہ ہے کہ میں اس معاملہ پر غور کرتا رہا ہوں۔

مجھے یہ سنکر بیحد خوشی ہوئی ہے کہ آپ کے صاحبزادہ عبدالسلام نے انٹرنس اور انٹرمیڈیٹ میں اسقدر شاندار کامیابی حاصل کی ہے۔ دعا ہے کہ آئندہ اس سے بھی بہتر کامیابی حاصل کرے۔

میں بھی اپنے زمانہ میں اچھا طالب علم شمار ہوتا تھا۔ یہی وجہ ہے کہ میاں افضل حسین صاحب نے مجھ سے مشورہ لیا ہے۔ ایف-اے میں میرے مضامین عربی-سائنس بی-اے میں ریاضی کے دونو کورس اور انگریزی آنرز تھے۔ ایم-اے میں ریاضی کا طالب علم تھا۔ میرے خیال میں آپ کے صاحبزدہ کو بھی یہی مضامین لینے چاھئیں۔ بی-اے میں ریاضی آنرز نہ کرنے کا نقصان ایم-اے ریاضی میں پورا ہو سکتا۔ آپ کا صاحبزادہ ہونہار ہے، آسانی سے کمی پوری کرلیگا۔

عام خیال یہ ہے کہ مقابلہ کے امتحانوں میں ریاضی کا مضمون فائدہ مند نہیں ہے۔ لیکن اچھے طالب علموں کو اتنی دقت نہیں ہوتی۔ میں نے صرف Lower Mathematics کا مضمون آئی-سی-ایس کے امتحان میں لیا تھا۔ اسمیں میرے نمبر ۲۰۰ میں سے ۱۹۰ آئے تھے۔ اب تو ریاضی کے مضامین غالباً ۸۰۰ نمبروں کے لئے جا سکتے ھیں۔

اے کورس اور عربی لینا بے معنی ہے کیونکہ اے کورس سے پڑھائی پوری نہیں ہوتی۔ ایک ھشیار لڑکے کے لئے عربی اپنے آپ تیار کر لینا کوئی مشکل نہیں ہے۔

ہسٹری اس مرحلہ پر پڑھانا مناسب نہیں ہوگا۔
اگر آپ لڑکے کو لاہور کے گورنمنٹ کالج میں بھیج سکیں تو اسکے لئے بہتر ہوگا۔ مگر ملتان کے کالج میں بھی کوئی حرج نہیں ہے۔
اگر آپ کو مجھ سے کسی مزید بات پر مشورہ لینا ہو تو میں حاضر ہوں۔ میرے لئے یہ نہایت خوشی کی بات ہے کہ مجھے ایسے ہونہار لڑکے کا علم ہو گیا ہے۔

نیاز مند——عبدالمجید

2. Mian Afzal Hussain's letter dated 23rd August, 1949 to Abdus Salam, and dated 12th June, 1951 to Chaudhary Muhammad Hussain.

Dakham House,
552, Model Colony,
Jehangir-Sethna Road,
Karachi.
23rd Aug. 1949.

My dear Abdus Salam,

I have just received your letter of 18th August and by this very post I also received a letter from Mr. Sharif. I have no doubt in mind that Mr. Sharif will do his very best for you. If you get a stipend of £600/— to continue at Cambridge for another two years you should consider yourself very fortunate. I have no doubt that they could offer you an appointment today and permit you to join after the completion of the course of your training at Cambridge. I am, howerver, doubtful if you could count your seniority from the date of this offer. The seniority usually depends on the date of taking over. In my own case, I was offered an appointment sometimes in July 1916 but I did not join till January 1918 lost that seniority. One has to take chances in all these matters. My advice to you would be to accept the stipend, complete your studies at Cambridge and not worry about the rest.

Many thanks for your good wishes. *Insha Allah* I will be leaving for *Hajj* on the 27th of next month.

With best wishes for your future.

Yours sincerely,

M. Afzal Husain

Abdus Salam, Esquire,
C/o Supdt.,
Office of the Inspector of Schools,
Multan City.

Pakistan Public Service Commission
Karachi.
12the June, 1951.

My Dear Mohd Husain Sahib,

My heartiest congratulations on Abdus Salam's brilliant success. Wherever he has been he has won laurels. We are all very proud of him and I know you must be particularly proud of his achievements.

Men like Abdus Salam do not belong to any community or country. Their place is amongst the most brilliant in the world and therefore they belong to the entire humanity. In my opinion wherever Abdus Salam has the facilities for work he should stay there and Pakistan should help him to stay there. His personal gain or the gain to his family or to his country would be insignificant as compared to the gain to science to which he is devoted and the advancement he makes will benefit all human beings whichever country they may be living in.

I am afraid Abdus Salam will not find facilities for work as good as they are in Cambridge or in any University in America but, I am sure, when he comes over and joins the Government College, Lahore, the Government would provide him whatever they can. Let us hope for the best.

With best wishes and repeated congratulations,

Yours sincerely,

M. Afzal Husain

Mohd Husain Sahib,
House No. 634,
Nawan Shehr,
Multan.

Sir Zafrullah Khan's Private Secretary's letter to Salam's father.

۶ - کنگ ایڈورڈ روڈ ــ نئی دھلی

۲۸-ماہ اخا ۱۳۱۹ھ

مکرمی - اسلام علیکم ورحمتہ اللہ و برکاتہ ــ آپکا خط ،
عزیز عبداسلام صاحب کی تصویر اور میاں انضل حسین صاحب کے
گرامی نامے کی نقل آنریبل سر محمد ظفراللہ خانصاحب کو ملی -- وہ
مبارکباد پیش کرتے ھیں اور دعا فرماتے ھیں کہ اللہ تعالیٰ اپنے فضل
سے عزیز کو اسلام اور سلسلے کیلئے مفید اور بابرکت بنائے - آمین -
انکی رائے میں بھی عبداسلام صاحب کو اپنی صحت کی طرف خاص
توجہ رکھنی چاھئے اور بجائے کتابوں کا کیڑا بننے کے ذھنی نشو و نما
کی طرف توجہ دینی چاھئے - کالج میں جو لیکچر کل پروفیسر نے دینا ھو
وہ اس سے پہلے آج اچھی طرح دیکھکر جانا چاھیئے تاکہ اچھی طرح
ذہن نشین ھو جائے اور پھر گھر آکر اسے دھرا لینا چاھئے - تیسرے
یہ کہ اگر سفر کا موقعہ ملے - جس کا علمی رنگ میں فائدہ اٹھایا
جا سکتا ھو - تو ضرور اٹھایا جائے - - چاھے محض سیر و تفریح کے
رنگ میں - یا علمی مجالس سے استفادہ حاصل کرنیکے لئے - گھر سے
نکلکر دوسرے علاقے دیکھنے سے دماغی وسعت پیدا ھوتی ھے -
اور یہ بجائے خود تعلیم ھے -

وسلام

خاکسار محمد شریف ، پرائیویٹ سکریٹری

فوٹو اور وائس چانسلر کے خط کی نقل واپس ارسالخدمت ھے -

4. Translation of Professor Pauli's letter to Professor Weisskopf.

TRANSLATION

Dear Weisskopf,

Now the first shock is over and I begin to collect myself again (as one says in Munich).

Yes, it was very dramatic. On Monday 21st at 8:15 p.m. I was supposed to give a talk about "past and recent history of the neutrino". At 5 p.m. the mail brought me three experimental papers: G.S. Wu, Lederman and Telegdi: the latter was so kind to send them to me. The same morning I received two theoretical papers, one by Yang, Lee and Oehme, the second by Yang and Lee about the two-component spinor theory. The latter was essentially identical with the paper by Salam, which I received as a preprint already six to eight weeks ago and to which I referred in my last short letter to you. (Was this paper known in the U.S.A.?) (At the same time came a letter from Geneva by Villars with the *New York Times* article.)

Now, where shall I start? It is good that I did not make a bet. It would have resulted in a heavy loss of money (which I cannot afford): I did make a fool of myself, however (which I think I can can afford to do)—incidentally, only in letters or orally and not in anything that was printed. But the others now have the right to laugh at me.

What shocks me is not the fact that "God is just left-handed" but the fact that in spite of this He exhibits Himself as left/right symmetric when He expresses Himself strongly. In short the real problem now is why the strong interactions are left/right symmetric. How can the stength of an interaction produce or create symmetry groups, invariances or conservation laws? This question prompted me to my premature and wrong prognosis. I don't know any good answer to that question but one should consider that already there exists a precedent: the rotational group in isotopic spin-space, which is not valid for the electromagnetic field. One does not understand

either why it is valid at all. It seems that there is a certain analogy here!

In my lecture I described how Bohr (Faraday lecture, 1932, Solvay Conference, 1932), as my main opponent in regard to the neutrino, considered plausible the violation of the energy law in the beta-decay (what one calls today "weak interaction"), how his opposition then became weaker and how he said in a more general way (1933) that one must be "prepared for surprises" not anywhere but specifically with the beta-decay. Then I said spontaneously (on the spur of the moment that at the end of my talk I would come back to the surprises which Professor Bohr had foreseen here.

He was not right with the energy law* but, who knows, will there be any stop after this new principle? According to it, perhaps the beta interactions are still "too strong" to violate also the energy law; but what if there are still weaker interactions for which also the energy law does no longer hold (as Bohr wanted it originally)?

One could perhaps also describe such a thing with the general formalism of wave mechanics (and field quantization): Imagine in the Hamilton operation an interaction term multiplied with a very small constant that depends explicitly on time (e.g. oscillatory); then you would get a thing like that.

Obviously one would say: The time dependence is an external field that supplies and withdraws energy. This way one turns things around. But one could try the same trick also with the left/right asymmetry. Take equation (23) on page 42 of my paper in the Bohr memorial volume (this paper now seems to become quite fashionable), let us imagine, for example, the terms with $C_1..C_5$ multiplied with a scalar field $\varphi(x)$, the terms with C_0—C_{10} multiplied with a pseudo-scalar field $\phi(x)$. For God Himself, Who can change the sign of ϕ such a theory would of course be right/left invariant—not for us mortal men, however, since we know nothing about that hypothetical new field except that here on earth it is practically constant in respect to time and space (static-homogeneous) and that we have no means of changing it.

Well, this is a very theoretical example. Why just a scalar field? I do not know whether one has really examined the Lorentz invariance of the interaction (one knows, of course,

it is so for free particles), why not just a vector field ϕ, and a pseudo-vector field ϕ ($k\lambda\mu$) whose 4-, or [1 2 3]-component, respectively, are much larger than the others? Incidentally, I have published a remark in 1936 (in a somewhat hidden passage) that the constant of the Fermi interactions could perhaps be proportional to the square root of the gravitational constant. No method exists to confirm such a hypothesis or to disprove it. I think, however, one should keep the possibility in mind that there is some unknown field involved here. That this is the case just for the weak interactions might have some special reasons which ought to be connected with the unknown physical nature of the fields. Many questions, no answers!

*Only in *Nature*, 1936, did he give in!

5. Professor Pauli's letter to Professor C.S. Wu who first established experimentally that parity is violated in weak interactions

Extracts from Gamma adventures in Experimental Physics

SUBSEQUENT DEVELOPMENTS

Immediately after the news was announced, I received a letter from Wolfgang Pauli in which he pondered on this combined "CP" invariance after learning the results of our experiments:

Zurich
Jan. 19, 1957

Dear C. S. Wu:

Exciting news is coming from the States (Blatt wrote it to me in a letter from Princeton) about an asymmetric angular distribution in your beta-decay experiment with directed nuclear spins, indicating a restriction of the left-right asymmetry of the theory in such a way that the left-right interchange must be coupled with a change of sign of the 'lepton-charge' (means neutrino $\rightleftarrows$ antineutrino, $\overset{+}{e} \rightleftarrows \bar{e}$). So it is, if I understood Blatt correctly.

When I considered such formal possibilities in my paper in the Bohr-Festival Volume (1955), I did not think that this could have something to do with Nature. I considered it merely as a mathematical play, and, as a matter of fact, I did not believe in it when I read the paper of Yang and Lee. *I did not believe Salam either, when I read this proposal to establish a connection between the above restriction in parity and the vanishing of the restmass of the neutrino. Salam's proposal has a certain beauty in itself; namely, it is equivalent with the description of the neutrino with a two-component spin only.*

What prevented me *until now* from accepting this formal possibility is the question why this restriction of mirroring appears only in the 'weak' interactions, not in the 'strong' ones. *Theoretically,* I do not see any interpretation of this

fact, which is empirically so well established. Do you know somebody in the States, who has real ideas about that?

Can you write me more about your work—of course only when you have time for it and when you are sufficiently sure about the results—and can you send me a preprint, when there will be one?

That Professor Pauli was perturbed by these dramatic events can be seen from the following lines:

In any case, I congratulate you (to the contrary of myself). This particle neutrino—on which I am not innocent—still persecutes me. On Monday, I have to give a more general lecture on old and new history of the neutrino. I have read much literature this autumn, including your article in K. Siegbahn's Handbook. It is fine, but I disagree with your discussion of the upper limit of the neutrino rest-mass which seems to me too high.

Discovery of Parity Violation in Weak Interactions

London:

Very few people outside the small circle of the world's outstanding physicists happen to know of the contribution a Pakistani scientist has made to theoretical physics early this year. Fewer still know his achievement in his own country.

This Pakistani scientist is Dr. Abdus Salam, who recently succeeded Professor Hyman Levy to the Chair of Applied Mathematics and Theoretical Physics at the Imperial College, South Kensington, London, which is reputed for its outstanding achievements in the field of research, and which as a result has been selected as the central institution for the training of scientific manpower to meet the competition from other countries.

Professor Salam's contribution to theoretical physics relates to what is called the "Reflexion-symmetry Principle" or the "Principle of Parity". Four names are associated with the development and theoretical verification of this theory. They are those of Prof. Salam of Pakistan, Prof. Landau of the Soviet Union, and two Chinese scientists, Professors Yang and Lee of the United States.

Professors Yang and Lee were the first to question the correctness of the right-left symmetry principle which had been accepted by all physicists up to then, in a paper published by them in the summer of 1956, and they proposed a number of experiments to decide whether the principle held or not. These experiments were carried out by another Chinese scientist, Mr. Wu, of the U.S.A., in the middle of January 1957 and the results confirmed the suspicions of Professors Yang and Lee.

Even prior to these experiments, Prof. Salam had predicted in November 1956 the exact results which the experiments would yield. He prepared a paper on the subject, giving his own

conclusions and exact quantitative calculations, which he sent to the Italian journal "*Il Nuovo Cimento*". This reached the editor of the journal on November 15. Earlier, he also sent a copy of the paper to Prof. Pauli, the Zurich professor and Nobel Prize winner, who is universally acknowledged as one of the world's topmost physicists. But so firm was his belief in the correctness of the parity principle that when he received Prof. Salam's paper he sent back the message: "Give my regards to my friend Salam and ask him to think of something better."

Subsequently after the results of the experiments were known, Prof. Pauli in his letters to Prof. Weisskopf. dated January 19 and 27, acknowledged having received Prof. Salam's paper several weeks before he got the paper of Professors Yang and Lee. Professors Yang and Lee themselves have acknowledged the fact that they had seen Prof. Salam's manuscript before they had written their own.

About the same time, a Russian scientist, Prof. Landau, working independently, developed the same theory in December 1956. Prof. Landau who is the Head of the Soviet Institute of Theoretical Physics, is counted among the top-most world authorities on the subject. Prof. Mendelssohn, F.R.S., one of the five leading British physicists who had recently attended a conference in Moscow on physics, in a signed article in the *Sunday Observer*, paid glowing tribute to Prof. Landau. He said: "Landau's school of theoretical physics in Moscow has, at present, no equal anywhere in the world. It can be compared only with the Sommerfeld school which flourished in the twenties in Munich and produced many of the theoreticians now holding leading positions in the West. . . . The flair for new ideas and original solutions, so assiduously fostered and encouraged, is an outstanding feature of Soviet physics, and the American witch-hunters have done the West a singular disservice by implying that Russian achievements depend on espionage. There is no doubt whatever that Soviet science can be completely self-sufficient, and that in any future interchange there will be as much give as take. Indeed, unless the Western Powers succeed in stepping up scientific development rapidly, they must face the possibility of becoming technologically inferior to the Russian within ten years."

It is, therefore, not the least surprising that Prof. Landau had independently arrived at the same results. His paper appeared in the journal "*Nuclear Physics*" in January 1957. Thus chronologically, Prof. Salam's paper came out a month earlier than that of Prof. Landau, which in its turn preceded that of Professor Yang and Lee by another month. These facts are already on record in scientific journals dealing with the subject and whenever the new theory is discussed in such journals the four names associated with its development are mentioned together, although in the popular Press, especially in the West, the names of the Chinese Professors alone have come out. As soon as the results of the new experiments were known, Professors Yang and Lee received such a blaze of publicity in the American Press that others who had preceded them in the enunciation of the principles were left in the penumbra of comparative obscurity. The American magazines, *Time*, *Life*, *Fortune*, *Scientific American*, and *Post*, of the same month published lengthy articles and Professors Yang and Lee shot into the scientific firmament as twin stars of blinding brilliance. The "*New York Times*" devoted four full pages to the report and published the full text of the manuscript of Yang and Lee, an unprecedented thing among daily newspapers in the West.

The new theory developed by the four scientists has a great bearing on the concept of elementary particles and is a valuable contribution to nuclear physics. It explodes the faith entertained by scientists from the days of Leibniz that nature did not recognize any inner difference between the right and the left. Since the time of Leibniz physicists had believed that in physical laws there was no distinction between the right and the left—popularly speaking the existence of the right hand implies that the left hand also must exist. Since the right hand is the mirror reflexion of the left, the principle is called the "Reflexion-symmetry Principle" or the "Principle of Parity".

As the British mathematical physicist and Nobel Prize winner Prof. P.A.M. Dirac, has shown that for a particle there must be an anti-particle, the law of space reflexion asserts that if a particle exists, the one obtained by reflecting it in a mirror must also exit. If a reaction can take place, the corresponding reaction seen in a mirror is also a physically

possible one. If right-polarized neutrinos can exist, so must the left-polarized neutrinos.

This principle has a philosophical appeal for many scientists. Apart from its philosophical appeal, this principle is known to be valid for all strong and electro-magnetic interactions. In the summer of 1956, Professors Yang and Lee pointed out that there had been no experiment so far to prove or disprove it for weak interactions, and therefore suggested a number of experiments which might determine whether this symmetry principle was true.

So deep was his faith in the correctness of the parity principle, that Prof. Pauli who is acknowledged as an eminent authority on the subject wrote in a letter to Professor V. F. Weisskopf, of the Massachussetts Institute of Technology on January 17, 1957: "I do not believe that the Lord is a weak left-hander, and I am ready to bet a very high sum that the experiment will give symmetric angular distribution of the electrons. I do not see any logical connection between the strength of an interaction and its mirror invariance."

Two days later he hastened to write another letter in which he said: "A quick addition to my last letter. Blatt has written to me that the experiment of Wu with the oriented nuclear spin gives a symmetric angular distribution for the electrons. Very exciting! How sure is this news? He also says that the neutrino and antineutrino are spatial mirror images. The Lord has in his left hand e^- in his right hand e^+".

By this time he had also received Prof. Salam's paper. In the same letter he also wrote: "This corresponds to an idea of Salam, who introduces a connection with the vanishing of the neutrino mass. This is equivalent with the description of the neutrino being a two-component spinor with zero mass, but why is this restriction of the mirror invariance only present with the weak interactions? Does anybody know about that?"

On January 27, Prof. Pauli again wrote: "Now after the first shock is over I begin to collect myself. Yes, it was very dramatic. On Monday the 21st at 8 in the evening I was supposed to give a lecture on the old and new history of the neutron. At 5 p.m. I received three exprimental papers by Wu, Lederman, and Telegdi. In the same morning, two

theoretical papers came by Yang and Lee and Ochme about the two-component spin theory. (This theory originates from Weyl, 1929, and was originally wrongly interpreted by him. My Handbuch article in 1932 reproduces my discussions about this with him).

"This theory is contained in essentially identical form in an earlier paper by Salam, which I received as a preprint already six to eight weeks ago. I wonder if it is known in the U.S.A.

"Now where shall I begin? It is good that I did not make a bet since it could have cost me a lot of money (which I cannot afford). This way I only have blundered in letters or orally and lost prestige (this I could afford, I think) but it is for you to laugh at me in this situation.

"I am shocked not so much by the fact that God is a left-hander, but by the fact that He still appears to be left-right symmetric when he expresses himself strongly. In short, the actual problem seems to be the question: Why are the strong interactions parity-symmetric? How can the strength of an interaction produce symmetry groups, invariances or conservation laws?"

Professors Yang and Lee to whom Prof. Salam had sent his paper did acknowledge the fact in their paper on "Parity non-conservation and a two-component theory of the neutrino". In Footnote 5, they wrote: "We have received a manuscript from Prof. A. Salam on a theory of the neutrino similar to the one discussed in the present paper. He specifically discussed points (A) and (B) that we discuss here. He also gave the Michel parameter for the mu decay that agrees with the ones obtained below in Sec. 6."

"Left-Eyed Giant"

Prof. Salam once explained to a classicist the significance of this discovery in physics in terms of classical legends. He asked the classicist if he could recall any instance in classical literature of a legend about a giant with only the left eye. He admitted that one-eyed giants did figure in classical mythology and proceeded to name them one by one, but they all sported their solitary eye in the middle of their forehead. Prof. Salam said that the new theory revealed space as a left-eyed giant,

and the pity of it was that there did not appear to be a right-eyed counter-part to it.

Returning instantly from this light-hearted digression into classical mythology, Prof. Salam in a recent lecture in London, explained the reason for the asymmetry. He said that one could give a deeper reason why the right-left symmetry should be violated whenever a neutrino was emitted. He said that it could be shown that an exactly zero mass for the neutrino was incompatible with the right-left symmetry. "We have lost the symmetry principle, but perhaps gained an exactly zero mass for the neutrino," he said. "Today the gain seems unimportant compared to the loss. A few years hence we may think differently."

Prof. Salam explained how he reached the conclusions before Yang and Lee had. He had heard of the work of the Chinese physicists in Seattle in September 1956. During a flight from New York to London, it struck him that in all the experiments proposed by Yang and Lee, an elementary particle, the so-called neutrino, was emitted. It was long suspected that the neutrino has a rest-mass very close to zero. Prof. Salam could show by a simple argument that an exactly zero mass for the neutrino was incompatible with the right-left symmetry principle. Perhaps nature preferred that the neutrino should have an exactly zero-mass and was willing to sacrifice even the reflexion-symmetry principle to achieve this. Starting from this Prof. Salam could predict exactly and quantitatively what the precise results of the experiments proposed by Yang and Lee would be. These experiments were carried out in the middle of January. Their results exactly tallied with the numbers Prof. Salam's calculations had produced.

The main credit for these experiments goes to a Chinese woman physicist, Mrs. Wu, who like Yang and Lee, is domiciled in the U.S.A. When the Chinese scientists received world-wide publicity Chiang Kai-shek's Kuomintang regime in Taiwan proudly claimed them as their nationals and conferred on them gold medals, and prizes of 1,000 $ each.

Life-Sketch

Professor Salam, who succeeded Prof. Levy to the Chair of Applied Mathematics and Theoretical Physics at the Imperial

College, is the youngest professor the college has ever had. He is only thirty-two. He is the first and the only person from any Commonwealth country to occupy this position and the first Asian to be appointed to the Chair of a Science faculty in any university in Britain. Professor Radhakrishnan who had once occupied a Chair at Oxford University, was only Professor of Indian Philosophy.

Prof. Salam was born in Jhang, in West Pakistan, in 1928. He had a brilliant educational career. He was a First Class student throughout and topped the list in the Matriculation, Intermediate, B.A. and M.A. examinations of the Punjab University. He set up a new record in the B.A. examination in 1944, which still stands. His distinction in the M.A. examination in 1946 won him a Government scholarship to join Cambridge University from where he took his Tripos in Mathematics in 1948 and Tripos in Physics in 1949 with a double first.

Subsequently, he was elected to a Fellowship at St. John's College, Cambridge, in 1951, for research work, in Meson theory, and a similar Fellowship in the Institute of Advanced Study (Einstein's Institute), Princeton, U.S.A. Returning to Pakistan with high hopes and still greater zest, he was appointed as Head of the Department of Mathematics, at the Government College, Lahore, in 1951, and in the following year he accepted the chairmanship of the Department of Mathematics in the Punjab University.

However, for a person of Prof. Salam's ability, attainments and inexhaustible zest for work Pakistan hardly offered the opportunity or conditions for the full play of his talents. He yearned for the opportunity, but none was visible within his limited horizon.

When Prof. Salam was leaving England in 1949, Prof. Levy had made a prophetic statement. He said that if ever Pakistan found that it had no use for Prof. Salam, the Imperial College would certainly have a place for him. Prof. Levy's words came true.

In 1954 Prof. Salam was invited to join Cambridge University as a Lecturer in Mathematics, which position he held until early this year when he succeeded Prof. Levy at the Imperial College.

Shortly after assuming the chairmanship of the Department of Applied Mathematics and Theoretical Physics at the Imperial College, Prof. Salam delivered the inaugural address of the Mathematics Society of the college, on "Elementary Particles", which was attended by many distinguished personalities. Introducing him, Prof. P M.S. Blackett, Nobel Prize winner and Professor of Physics at the college, said: "Dr. Salam had a meteoric academic career at school in Pakistan and seemed to possess an extraordinary facility for being unable to pass any examination in any subject except at the very top of the list. In 1946 he migrated to Cambridge and came to the greatest decision of his life, a decision which affected us here when he had to make up his mind whether to take an M. A. in English literature or in Mathematics. Luckily for Physics and Imperial College he chose the latter."

After referring in very eulogistic terms to the other aspects of his career, Prof. Blackett said: "In 1955 he showed his administrative gifts by becoming one of the scientific secretaries of the great international conference at Geneva on the peaceful uses of atomic energy. Salam's work in theoretical physics has been mainly of a very abstract kind, originally dealing with Quantum Theory of Fields, a subject of which I both do not know anything and know I'll never understand. Latterly he has gravitated towards the field of Elementary Particles, which is a very familiar and dear one to myself and to my young colleagues here in other parts of England and in the world, and this is what he is going to talk about today."

Prof. Salam has just returned to London after a visit to Argentina, Brazil and France. He spent two weeks at Buenos Aires lecturing on nuclear energy at the invitation of the Atomic Energy Commission of Argentina. He also had a week's stay at Rio-de-Janeiro where he delivered some lectures on the same subject. At the Invitation of the French Government he visited the International Theoretical Physics Summer School at Les Houche where he gave a series of lectures. Next month he is visiting Italy to deliver a series of lectures on Elementary Particles.

7. **Professor Abdus Salam's note on the establishment of "Islamic Science Foundation" on 2nd July 1973:**

ISLAMIC SCIENCE FOUNDATION

1. This is a proposal for the creation of a Foundation, by Islamic countries, with the objective of promotion of science and technology at an advanced level. The Foundation (working in conjunction with the Islamic Conference) would be sponsored by the Muslim countries, and operate within these, with an endowment fund of $1,000 million and a projected annual income of around $60-$70 million. The Foundation will be non-political, purely scientific, and run by eminent men of science and technology from the Muslim world.

2. Need

No Muslim country, in the Middle East, in the Far East or Africa possesses high level scientific and technological competence attaining to any international levels in quality. The major reason is the persistent neglect by Governments and society in recent times in the acquiring of such competence. In relation to international norms (around .3% of economically active manpower engaged in higher scientific, medical and technological pursuits, with around 1% of GNP spent on these) the norms reached in the Islamic world are one tenth of what one should expect for a modern society.

3. Objectives of the Foundation

It is suggested that a well-endowed Islamic Science Foundation be created with two objectives: *building up of high level scientific personnel and building up of scientific institutions.* In pursuit of these objectives:

(a) The Foundation will create *new communities* of scientists in disciplines where none exists. It will strengthen those communities which do exist. This will be done in a systematic manner, with the urgency of a crash programme.

(b) The Foundation will help in building up and in strengthening *institutions* for advanced scientific research at international level, both in pure and applied fields, relevant to the needs of the Muslim countries and their development.

The emphasis of the Foundation's work would lie in building up sciences to *international standards of quality and attainment*. Of the two objectives listed above, the building up of high level scientific personnel will receive higher priority in the first stages of the Foundation's work.

4. Programme

In pursuance of its twin objectives: [(a) of building up high-level scientific manpower in a systematic manner, and (b) of employing this manpower for advanced work for the betterment and strength of Islamic societies] the Foundation will pursue the following programme:

(a) Building up of Scientific Communities

(i) Scholars will be sponsored by the Foundation to acquire knowledge of advanced sciences, wherever available, in areas where gaps exist and where there are no existing leaders of sciences. After their return to their countries, the Foundation will help them to continue with their work. Funds of the order of $10 million would support some 4,000 scholars annually while they are receiving advanced training, and support around 1,000 scholars and the needed facilities on their return.

(ii) Programmes will be organized around existing scientific leaders in order to increase high level scientific manpower. For this purpose contracts will be awarded to University departments to strengthen their work in selected fields. *Quality* of the University faculties will be the criterion for the award of these contracts. Funds to the total of around $15 million may be spent annually for these contracts.

(iii) *Contract of scholars from the Islamic world with the world scientific community.* Existing science in Muslim countries is weak because of its isolation. There are no contacts

between scholars in Muslim countries and the world scientific community, principally on account of distance. Science thrives on the interchange of ideas and on continuous criticism. In countries with no international scientific contacts, science ossifies and dies. The Foundation will endeavour to change this. This will entail frequent two-way visits of fellows and scholars, and holding of international symposia and conferences. Funds of the order of around $5 million will subsidise some 3,000 visits a year of around two months' duration. This, spread over around 10 sciences and over 15 countries, is about 20 visits a year from any one country in any one science.

(b) Sponsoring of Relevant Applied Research

The Foundation may spend around $25 million for the strengthening of existing, and the creation of new research institutes on problems of development in the Middle East and the Islamic world. These new institutes of international level and standing would be devoted to research in problems of health, technology (including petroleum technology), agricultural techniques and water resources. These institutes may also become units of the United Nations University system in order to attain international standards of quality and achievement through contact with the international community. (A successful institute like the International Rice Institute in the Philippines costs about $5—$6 million to create and about the same amount to run at an *international* level.)

(c) The Foundation may spend around $5 million in making the general population of Islamic countries technologically and scientifically minded. This will be achieved through instruction using mass media, through scientific museums, libraries and exhibitions, and through the award of prizes for discoveries and inventions. An appreciation of science and technology by the masses is crucial if there is to be a real impact of science and technology.

(d) The Foundation will help with the task of modernising syllabi for science and technology at the High School as well as at University levels.

5. Functioning of the Foundation

(a) The Foundation will be open to sponsorship by all Islamic countries which are members of the Islamic Conference.

(b) The Foundation will have its headquarters office at the seat of the Islamic Conference. In order to retain active and continuous contact with the research centres and projects it endows, it may set up subsidiary offices as well as employ scientific representatives, resident or at large.

(c) The Board of Trustees of the Foundation, which will be responsible for liaison with the Governments, will consist of representatives of the Governments, preferably scientists. The endowment fund of the Foundation will be vested in the name of the Board of Trustees.

(d) There will be an Executive Council of the Foundation which will consist of scientists of eminence from the Muslim countries. The first Council and its Chairman (who will also be the Chief Executive of the Foundation) will be appointed by the Board of Trustees for a five-year term. This Council will decide on the Foundation's scientific policies, the expenditure of the funds, their disbursement and their administration. The work of the Foundation and the Executive Council will be free from political interference. The Board of Trustees, through the statutes, will be charged with the responsibility of ensuring this.

(e) The Foundation will have the legal status of a registered non-profit making body and would have a tax-free status both in respect of its endowments as well as emoluments of its staff.

(f) The Foundation will build up links with the United Nations, UNESCO and the United Nations University system, with the status of a non-Governmental organization (NGO).

6. Financing of the Foundation

(a) It is envisaged that the sponsoring countries would pledge themselves to provide the endowment fund of $1,000 million in four yearly instalments.

(b) The proportion of the endowment fund to be contributed by each sponsoring country will be a fixed fraction of the export earnings of the country. The 1972 schedule of export earnings for the Muslim countries is appended. In future years these earnings are expected to increase. However, even at the 1972 level of 25 billion dollars per year, a contribution of less than one per cent per country per year would suffice to build up the initial endowment capital of one billion dollars over four years.

ABDUS SALAM

2 July, 1973

1972 Merchandise Exports[1] of Muslim Countries

(In millions of U.S. dollars)

Afghanistan	84***	Mauitania	101**
Algeria ..	1,009	Morocco ..	498
Bahrain ..	267*	Nigeria	1,811
Bangladesh ..	270****	Oman ..	147
Chad ..	44**	Pakistan ..	550***
Gabon ..	174**	Quatar ..	275**
Egypt ..	789	Saudi Arabia	3,845
Indonesia ..	2,061	Sierra Leone ..	100
Iran ..	2,642	Somalia ..	34
Iraq ..	1,538	Sudan ..	329
Jordan ..	32	Syria ..	195
Kuwait ..	2,407	Trucial States ..	790
Lebanon ..	242	Tunisia ..	219
Libya ..	2,863	Turkey ..	882
Malaysia ..	1,636	Yemen (People's)	105
		Total:	25,939

[1] Except where otherwise indicated by: * for 1971, ** for 1970, *** for 1971-72 and **** for 1972-73.

Note: Since 1974 the import earnings of oil producing countries have gone up by a factor of between 2.5—3.

April 1975.

8. An abridged version of Salam's paper on "Ideals and Realities".

IDEALS AND REALITIES*

I am deeply honoured and much appreciate the opportunity to give the first lecture in this series on Human, Global and Universal Problems, particularly just after the conclusion of one of the most momentous of special sessions of the United Nations General Assembly dealing with this subject. This session, as you all know, was convened to discuss the global crisis in the human family's continuing and near-permanent polarization between the rich and the desperately poor and the latter's demand for a *New International Economic Order*. I have looked forward to the opportunity of speaking to you to-day because I know that Sweden is one of the few countries of the world which has understood the issues; it is the ONLY country at present which is fulfilling the United Nations targets of aid. Its youth led the world in 1972 so far as global concerns go. My purpose today is to have a dialogue with you and to explore what are the ways in which the almost total incomprehension among the rich nations of what the poor are really demanding can be removed—and the urgency of the crisis mankind is facing brought home to developed societies.

The short-term crisis the world faces is simply this. The developing world—some-nine tenths of humanity—is bankrupt. We—the poor—owe the rich—one tenth of mankind—some 50 billion dollars. The poorest amongst us cannot even pay the interest on our borrowings—far less find the 10 billion dollars we collectively need to import 10 million tons of cereals every year to feed ourselves. My own country, Pakistan, owes some 6 billion dollars—roughly equal to Pakistan's GNP for one year, roughly equal to Pakistan's six years' export earnings. Last week's London's prestigious *Economist* magazine starkly said: "The poorest among the poor who can neither borrow more nor draw on reserves will cut on their imports—their people will simply starve".

But this short-term crisis is only a part of a longer-term crisis. Our world is terribly unbalanced in income and in consumption. At least three quarters of the world's income,

* Lecture to students of the University of Stockholm, 23 September, 1975.

three quarters of its investment, its services and almost all of the world's research are concentrated in the hands of a quarter of its people. They consume 78% of its major minerals, and for armaments alone, as much as the rest of the world combined. In 1970, the world's richest one billion earned an income of $3,000 per person per year; the world's poorest one billion, no more than a $100 each. And the awful part of it is that there is absolutely nothing in sight—no mechanism whatsoever—which can stop this disparity. Development on the traditional pattern—the market economics—is expected to increase the one hundred dollars per capita of the poor to all of one hundred and three dollars by 1980, while the $3,000 earned by the rich will grow to $4,000—that is an increase of $3 against $1,000 over an entire decade.

No wonder the poor nations consider visions of any growth and development on the traditional economic system a vicious fraud. This is the system which in the last 20 years created liquidity and credits of 120 billion dollars allocating just 5% of these to the poor nations. This is the system which pays 200 billion dollars for world commodities, but only one sixth of this reaches the primary producer himself—the rest, five sixths, going to the distributor and the middleman in rich countries—this is the system which gave 7 billion dollars of aid last year and took away almost exactly the same amount from the poor in depressed commodity prices. No wonder they are demanding in Omar Khayyam's words: "Ah love! could thou and I with fate conspire, to grasp this sorry scheme of things entire, would not we shatter it to bits—and then remould it nearer to the heart's desire."

Over the past three to four years, some of the brighter young economists of the Third World countries, Brazil, Mexico, Algeria, Pakistan and others—helped by some of the most distinguished figures in World Economics—have been groping towards a new synthesis of development and outer limits of growth. I am ashamed for my own profession, for there were no scientists or technologists associated with them. It is this new synthesis—embodied in the so called Cocoyoc and Rio declarations—which formed the basis of the Resolution on a Declaration on Establishment of a New International Economic Order, adopted in 1974 by the sixth special session

of the United Nations Assembly. The present session—just concluded, was the follow-up from the last—it was convened to put some teeth into the Charter of Economic Rights promulgated by the United Nations Assembly in 1974.

Among the poor—these Declarations have been likened to the great Declarations of Rights of Man in the 18th century by Tom Paine—and the Communist Manifesto of the 19th century. What the establishments in the richer countries really think of the International Economic Order is hard to fathom. During 1974, the reaction might have been typified by the words of one of the richer nations' delegates to the United Nations who referred to the "shadow world of rhetoric" and "The drawback of so many short-lived resolutions, each longer than the last, one a repetition of the other, virtually unreadable....". This year, though the response was still not outright commitment, Dr. Kissinger presented to the Assembly, on behalf of the richer nations, a welcome package of co-operative funds, joint institutes and aid initiative. I shall speak of these later, but in any case what is needed is not just that the Foreign and Finance Ministeries of the developed countries should respond to the demands of the poor, but that the intellectuals and the general public become aware of these and truly comprehend them.

In this spirit, I shall therefore try to convey to you how a humble natural scientist from a developing country—who is not an economist, but one who passionately loves the United Nations and its work—views the global crisis of the disparity of the rich and the poor.

To get behind the psychological thinking of the poorer humanity, you must understand how recent in our view this disparity—which makes untermenschen of us today —is. It is good to recall that three centuries ago, around the year 1660, two of the greatest monuments of modern history were erected, one in the west and one in the east; St. Paul's Cathedral in London and the Taj Mahal in Agra. Between them, the two symbolize, perhaps better than words can describe, the comparative level of architectural technology, the comparative level of craftsmanship and the comparative level of affluence and sophistication the two cultures had attained at that epoch of history.

But about the same time there was also created—and this time only in the west—a third monument, a monument still greater in its eventual import for humanity. This was Newton's Principia, published in 1687. Newton's work had no counterpart in the India of the Mughuls. I would like to describe the fate of the technology which built the Taj Mahal when it came into contact with the culture and technology symbolized by the Principia of Newton.

The first impact came in 1757. Some one hundred years after the building of the Taj Mahal, the superior firepower of Clive's small arms had inflicted a humiliating defeat on the descendants of Shah Jahan. A hundred years later still—in 1857—the last of the Mughuls had been forced to relinquish the Crown of Delhi to Queen Victoria. With him there passed away not only an empire, but also a whole tradition in art, technology, culture and learning. By 1857, English had supplanted Persian as the language of Indian state and learning. Shakespeare and Milton had replaced the love lyrics of Hafiz and Omar Khayyam in school curricula, the medical canons of Avicenna had been forgotten and the art of muslin making in Dacca had been destroyed making way for the cotton prints of Lancashire.

The next hundred years of India's history were a chronicle of a more subtly benevolent exploitation. I shall not speak of this, but only of the scientific and technological milieu I was brought up in as a young man in British India. The British set up something like 31 liberal High Schools and Arts Colleges in what is now Pakistan, but for a population then approaching 40 million people, just one College of Engineering and one College of Agriculture. The results of these policies could have been foreseen. The chemical revolution of fertilizers and pesticides in agriculture touched us not. The manufacturing crafts went into complete oblivion. Even a steel plough had to be imported from England. It was in this milieu that I started research and teaching in modern physics some 25 years ago at Lahore, in the University of the Punjab.

Pakistan had then just won its independence after one hundred years of British rule. We then had a per capita income of $80 a year, a literacy rate of 20%, a population growing 3% a year and an irrigation system for agriculture which was

breaking down. There was no social security and there was high child mortality—only five children out of twelve lived beyond one year. A child—a male child—was the only social security for old age one could budget for, making high birth rate imperative.

Pakistan—very willingly—accepted to become part of the free world economic bloc. We were relieved of worries of increasing population needing growing of more food. The US surpluses of wheat—under P.L. 480—gratefully came, at first, in such abundance that one of our Finance Ministers spoke of curtailing wheat cropping in Pakistan by law to grow tobacco instead. We imported highly talented Development Planners from Harvard University. They told us we did not need to put up a steel industry. We could in any case buy any amount from Pittsburgh. We leased out our oil imports and even the distribution of petroleum products within the country to multi-nations who conducted—in that age of oil surpluses—a half-hearted search for it.

Pakistan was thus a classic case of a post-colonial economy; political tutelage was interchanged for an economic tutelage. In the scheme of things, we were to provide cheap commodities—principally jute, tea, cotton, raw unprocessed leather. It was in 1956 that I remember hearing for the first time of the scandal of commodity prices—of a continuous downward trend in the prices of what we produced, with violent fluctuations superposed, while industrial prices of goods we imported went equally inexorably up as a consequence of the welfare and security policies the developed countries had instituted within their own societies. All this was called Market Economics. And when we did build up manufacturing industries with expensively-imported machinery—for example, cotton cloth—stiff tariff barriers were raised against these imports from us. With our cheaper labour, we were accused of unfair practices.

To give you an idea of these tariffs—suppose Pakistan exported cotton seeds, these would attract only \$100 a ton as tariff. But woe-betide if the seed was crushed into oil. The oil fell into the category of manufactures, and the tariff shot up to \$600. We were to be markets for steel, for machinery, for fertilizer, for armaments. We must not export anything remotely resembling manufacture. No wonder we have been bankrupted.

Of indigenous science and technology—or indeed of any technological manpower development—there was neither need, nor appreciation, nor any role for it. Any technology we needed, we bought. It came hedged with all types of restrictions. For example, no product which used this technology could be exported. And in any case, not all technology was for sale. Pakistan, for example, could not buy the technology of penicillin manufacture in 1955. My brother, together with a few other young chemists from Pakistan re-invented the process; producing as a result of their inexperience, penicillin at 16 times the world price. In the early 1950's, I looked upon my future as contributing to Pakistan's advance to technology and development as non-existent. I could help my country in only one way—as a good teacher—and that was to produce more physicists, who for lack of any industry, would in their turn, become teachers themselves, or leave the country.

But soon it became clear to me that even this role—that of a good teacher—would increasingly become impossible for me to maintain. In that extreme isolation in Lahore, where no physics literature ever penetrated, with no international contacts whatsoever and with no other physicists around in the whole country, I was a total misfit. I knew that all alone, I had no hope of changing Pakistan policies, so far as valuing science and technology were concerned. There was but one recourse, to make a call on the international scientific community to help in preserving one's professional integrity. My hope lay with the United Nations Organization and its agencies. And thus in 1954 started my involvement with these.

It is now two decades since I have been engaged in a very humble way with science and international affairs. I can divide this period into two distinct decades—the first decade from 1954 to 1964—the decade of innocence and hope—and the second decade 1964 to 1974, of growing frustration and a feeling of hopelessness of it all. The third decade is beginning for me now. Perhaps this decade will bring more hope.

But to go back to my personal story; the first opportunity I got of playing a minor role in public affairs came in 1955 with the Atoms for Peace Conference held in Geneva. You may recall that this was the first scientific conference held under the United Nations auspices, the first conference when East-

West secrecy, which extended till then to even trivial scientific information like neutron scattering cross-sections, was partly lifted. At this conference was promised atomic plenty to the world for energy, for isotope applications, for new and revolutionary genetic varieties of crops.

For me personally, this conference was important, for this was my first introduction to the United Nations. I remember entering that Holy Edifice in New York in June 1955 and falling in love with all that the organization represented—the Family of Man, in all its hues, its diversity, brought together for Peace and Betterment. I did not then realize how weak an organization it was, how fragile and how frustrating in its inaction, but I shall speak of this later. It seemed to me then that any ideas I may have of helping Pakistan physics—and developing countries' physics—must be implemented through United Nations action.

The second occasion when I came in contact with the organization came in 1958, at the Second Atoms for Peace Conference. This conference was similar to the one in 1955; its major achievement was a furthering of the process of disclassification of nuclear fusion. For me, the greatest gain was that I had the privilege of working as a secretary under one of the greatest Swedes in international affairs—Dr. Sigvard Eklund—now Director General of the International Atomic Energy Agency. From that date, started a most cherished personal friendship and one which transformed my life.

One consequence of the 1958 conference was that the Pakistan Government became interested in atomic energy. Pakistan has no oil, little gas, some hydro-potential. Pakistan needs atomic energy. In 1958, President Ayub Khan assumed power; I was recalled to Pakistan and asked to help with the creation of an Atomic Energy Commission.

We decided that in the absence of any other scientific organization in the country, it was our mandate to create research teams and research institutes in all fields of national endeavour —agriculture, health, besides an atomic industry. For this and to fulfil the needs of Pakistan universities, we must train in the great institutions of the world, mathematicians, chemists, physicists and agriculturists.

We instituted a training programme for scientific manpower within our meagre resources. I say meagre, because at its peak, the total research expenditure in all universities and all research establishments in Pakistan never exceeded 4 million dollars—a sum which you in Sweden spend on one department of physics in one university. With these meagre outlays, it was clearly impossible for Pakistan science to achieve any semblance of excellence. For ending the isolation of Pakistan science—the problem I had faced—we would still depend on international help.

For mobilising this help, an opportunity came in 1960 when I was fortunate to represent Pakistan at the General Conference of the International Atomic Energy Agency, in Vienna. I suggested at this conference that the international scientific community represented through the scientific agencies of the United Nations organization should accept as one of its responsibilities the caring for its deprived members—that there should be set up a network of first-rate international centres—in various pure and applied disciplines of science and technology which should offer their facilities principally to short-erm senior visitors from developing countries. I envisaged a system of associateships available at these centres—through which top scholars from developing countries would be given long-term—five years—appointments enabling them to spend three months of their summer vacation working together with their peers from developed countries at these centres, recharging their batteries and taking back with them newer ideas, newer techniques, newer impetus. This would end the isolation which, for example, I had suffered and which, in my view, was the principal cause of brain-drain of scientists—in contrast to the brain-drain of doctors or engineers.

In 1961, the values of high level scientific and technological contacts were rather strikingly brought home to us in Pakistan. Pakistan had inherited from the 19th century one of the most extensive networks of irrigation canals—some 10,000 miles long—irrigating 23 million acres of land. Some of these canals were as large as the Colorado River. They were carefully designed as to width, depth and slope in such a way that silty water moved just fast enough so that it neither eroded their beds nor chocked them by depositing sediment.

But in 1961 something had gone grievously wrong with the system. After a few decades of operation, the canal network slowly began to stifle the very fertility it was meant to create by spreading the blight of water-logging and salinity in areas through which the canals passed. One million acres of land were passing out of cultivation every year during 1950 to 1960.

In 1961, Professor J. Wiesner, President Kennedy's Science Advisor, assembled a team of university scientists, hydrologists, agriculturists and engineers, led by Roger Revelle to advise on this problem of water-logging and salinity. This team suggested continuous pumping out of saline water to lower the water table, but with the important caveat that the pumping operation must be simultaneous over a contiguous area as large as a million acres—otherwise the quantity of water seeping in from the periphery would exceed the quantities pumped out. Pumping had been tried on parcels of land smaller than one million acres, but proved ineffective. Some of you may recall that Blackett during the last war was called upon to suggest to the British Admiralty whether merchant ships should cross the Atlantic in a few large convoys or many small ones—given that the number of available destroyers protecting against enemy submarines was fixed. Noting that ratio of area to circumference maximizes with large radius, Blackett had suggested fewer large convoys rather than many small ones. Revelle's team's suggestion for Pakistan was a remark equally simple and it equally simply worked.

My next involvement with the United Nations system — and also the first disenchantment with the establishments representing their countries at this forum — came in 1962 when Dag Hammerskšld projected a United Nations Conference to be held the following year, on Science and Technology. He had the vision of transforming the developing world — through technological projects like the one I have just mentioned. I had the privilege of a long interview with Dag — the only time I met him — and to share his semi-mystical reverence for what science and technology — if applied meaningfully — could achieve for the poor. He recognized clearly that this needed first and foremost investment, even if relevant technology was available. Much more even than the leaders of the developing world, he recognized that it was important

to establish an indigenous scientific capacity in developing countries for research and development. This was needed, at the very least, to achieve an awareness of the significant development of world science and technology, an awareness which would enable a country to select and negotiate the purchase and ensure the effective assimilation of technology which its economic and social objectives required. He recognized that it is not just know-how which the developing countries need; it is also the *know-why*, if technological development was to be a graft which should take in the poorer world.

The conference proposed by Hammerskjöld was held in 1963, unfortunately after his tragic death. We, from the developing countries, proposed the creation of a World Science and Technology Agency — a Technical Development Authority, backed by an interantional bank for technological development. Besides strengthening indigenous science in developing countries, the Authority would have acted as a planning and programming body which would carry out feasibility studies, devise programmes and arrange their implementation. Being a United Nations organization it would associate with its work and give maturity to local scientific and technological organizations and talent, giving them training and intimate knowledge of the complex new techniques. Its very existence would have emphasized what the planning economist so often forgets — that the modern world and its problems are a creation of modern science and technology.

We proposed this; we lobbied for this, but we met with a complete blank wall of incomprehension — or worse — from the delegates from the industrialized countries — who, by and large, opposed the idea of any such Science and Technology Agency. It seemed that they preferred the scientific and technological effort of the United Nations to remain weak and fragmented within the system. There appeared no desire on their part to share technology with the developing world except through the existing system of licensing, operating in the manner I have described earlier in the context of Pakistan and the story of penicillin manufacture. The net legacy of this conference was the creation of an 18-man Advisory Committee on Science and Technology. We met

for eleven years — twice a year — after eleven years labour, we have recommended yet another United Nations Conference on Science and Technology to be held in 1978, this to meet and create the same Science and Technology Development Agency we proposed fifteen years ago. This time we are likely to get this because Dr. Kissinger gave the proposed Conference his blessing three weeks ago.

I was meeting the same incomprehension in respect of my second suggestion at the forum of the IAEA regarding the idea of the creation of a Theoretical Physics Centre, particularly from some of the countries where theoretical physics in fact flourishes. One delegate went as far as to say: "Theoretical physics is the Rolls-Royce of sciences — what the developing countries want is nothing more than bullock-carts.". To him a community of 25 physicists and 15 mathematicians, all told, trained at a high level for a country like Pakistan with a population of 60 million, was simply 40 men wasted. That these were the men responsible for all norms and all standards in the entire spectrum of Pakistan's education in physics and mathematics was totally irrelevant. He was himself an economist, who had wandered into a scientific organization like the IAEA. He could fully understand that we needed more high level economists, but physicists and mathematicians — that was wasteful luxury.

For the first time, it also began to be borne in upon me, how weak the United Nations system really was in terms of resources. Even to day, 12 years later, the United Nations family has miniscule resources. Let me give you the figures. (Fig. Table 1)

The total of the funds within the United Nations system for development do not add up to the funds available, for example, to the Ford Foundation — and this for service to 140 nations of whom 82 are desperately poor. The United Nations was created as a community of equal nations — but some were more equal than others. It was financially weak because the rich nations would not contribute to its revenues; it was functionally weak because the powerful nations respected its resolutions only when they were extensions of the decisions of their own foreign policies.

In 1964, when IAEA did agree to the Physics Centre, its Board voted us a sum of $55,000 to create an International Centre. Fortunately, the Government of Italy came through with an annual grant of $350,000 and the Centre was set up in Trieste.

To complete the story of the Centre, it started operating in 1964. It is now co-sponsored by IAEA and UNESCO, together with UNDP, who both contribute around a ¼ million dollars each; plus the Italian Government with a grant of $350,000 and SIDA with a grant of $100,000. During the 11 years of its existence so far, it has received some 6,000 senior physicists from 90 countries — 4,000 of them from 65 developing countries. It has truly created something of a revolution so far as the studies of physics are concerned, so far as the developing world is concerned. Over the years it has tended more and more to emphasize technology transfer in physics. In this, we have particularly been helped by a Solid State Committee headed by Professor J. Ziman of Bristol and Professor S. Lundqvist of Chalmers in Gothenburg. Two weeks ago, we inaugurated the first ever extended-three-month Course on the Physics of Oceans and Atmosphere, attended by some 60 senior physicists, meteorologists and ocean-scientists from some 30 developing countries. The Centre, however, still remains a singularity — the one isolated Centre within the United Nations family of its kind in the entire spectrum of advanced scientific knowledge.

After 1963, the disillusionment with the existing international order came fast. You know the history of this decade as well as I do. President Kennedy with whom, rightly or wrongly, the liberal aspirations — also about world development — got linked, was assassinated.

Around 1968, was the beginning of the student revolt and the realization that the environment was being wrecked. I felt then and still feel — and this is why I am speaking to you today — that the developing world lost a great moment, lost a great potential alliance, a great potential source of strength when the protesting energy of world youth concentrated on the one issue of environment and did not espouse at the same time the more embracing cause of world development.

In between these years came the repeated failure of UNCTAD conferences convened to propose a redress for relatively ever-falling commodity prices. It is good to be reminded today that the price of petroleum fell decisively between 1950 and 1970 — down to one dollar a barrel, stimulating a growth in energy use of between 6% to 11%. The reception of UNCTAD's proposals — its fervent appeals for some stability and indexation of commodity prices — were received with derisory scorn, typified even today by the influential London *Economist* writing in its issue of 30 August this year on the eve of the United Nations Conference: "The notion that the price of each commodity can be tied, not to the demand for it, but to the average rise in the price of manufactured goods, is a proposal to try to repeal, by some conference fiat, the Laws of Supply and Demand. The industrial countries should simply refuse any concessions to this proposal." And this in a year which saw the index of manufactures' prices go up to 140, while commodity price index hovered around 114. Thus, in this one year alone, the poor have subsidised the welfare economies of the rich to the extent of 26% of their earnings.

In 1972 came the great Conference on Environment in Stockholm. It was significant not just for pinpointing that environment was being wrecked and that some countries were contributing more than their fair share towards wrecking it. Even more important, it thrust into prominence the inter-dependence of the human community in solving the issues raised.

In 1972 came also the Club of Rome report on Outer Limit to Growth — with the thesis that world resources are finite and simply could not sustain infinite growth of industrialized economies. It is not well known that the poor countries had received a sharp reminder of this — as early as mid-1972 — in the form of a precipitous doubling of the price of wheat. This had happened because the failure of the crops in USSR made them buy 30 million tons of grain, nearly exhausting the world grain reserves. This was one of the contributory causes of the three-fold increases in oil prices; followed by yet another doubling of grain prices. Add to this the waning of the resource transfers of foreign aid programmes — the one colllective commitment of the western countries — and you

can understand the origins of the short-term crisis — the financial bankrupcy of poor humanity — with which I started my lecture.

To complete the story of foreign aid, the 17 richest nations allocated .03% of their GNP's to overseas development last year, compared with ·52% in 1960. While Sweden generously earmarked ·72%, UK and USA provided .30% and .25% respectively. The World Bank estimates that by 1980 the average of the 17 countries will be .28% and of US .18%. Contrast this with the US contribution at the beginning of the Marshal plans of 2.79% of GNP. Ministries in rich countries usually dismiss as unrealistic the United Nations target of allocating .7% of their GNP to aid. Yet this target could probably be reached in the second half of this decade if they merely devoted 2% of the increased wealth — the $1,000 per capita growth I spoke of before — which is expected to accrue to the industrialized nations in the next few years. At the United Nations Conference just concluded, EEC ministers did announce their readiness to try to meet the .7% target in 1980, though unfortunately, UK and USA expressed reservations.

Realizing these stark facts, and realizing that the developed world was unlikely to produce a Messiah — or even a Keynes — who would preach social justice between nation and nation, the developing countries decided in 1974 to use the forum of the United Nations for calling for New International Economic Order.

The New International Economic Order

What is the International Economic Order? The Rio Declaration, perhaps somewhat more radical than the United Nations Resolution, starts with the preamble: "Developed countries — by and large — have shown remarkable reluctance to initiate and support change. Having derived much of their wealth from cheap resources and raw materials of developing countries, they still refuse to give access to their markets to the Third World. They refuse to recognize the invitability of modifying their life styles, and scale and patterns of consumption, the maintenance of which requires a disproportionate share of world resources. They have used the power

provided by science and technology to pursue policies shaped by selfish interests over the world's oceans, and they are squandering a vast fraction of mankind's resources, in scientific manpower as well as materials, in stockpiling of weapons of mass destruction.". The document then goes on to say: "The struggle of the Third World is for *Economic Liberation*, greater equality of opportunity and securing of right to sit around the bargaining tables as equals with a redistribution of *future* growth *opportunities*. In the last analysis, we must look on the demand for the New International Order as a part of a historical process, as a movement, to be achieved over time."

The United Nations Resolution on the New Order is perhaps somewhat more muted; it starts with a call for a commitment from makind for the banishment of poverty and prevailing disparities; it calls for a just and equitable relationship between prices of raw materials and manufactured goods; it calls for access to the achievements of modern science and technology; it calls for an end to wasteful consumption — particularly in respect of food and expenditure on armaments.

In order to see how the ideals expressed in the United Nations Resolutions are carried out into realities, it is perhaps worthwhile to consider food and military expenditures in somewhat greater detail.

Food

In November 1974, the United Nations convened a Conference in Rome on Food. This Conference adopted the following declaration: "Within a decade no child will go to bed hungry and no family will fear for its next day's bread and no human being's future will be stunted by malnutrition.". To achieve this target, a World Food Council was set up, with the minimum target of distributing 10 million tons of grain a year as food aid, and achieving average 3.6% increases per year in food production by poor countries, through an international provision of agricultural inputs.

On 29 June 1975, the *London Times* reported: "The World Food Council ended its inaugural meeting here in Rome at 2.00 a.m. yesterday. It was saved from being an obvious farce and a failure only by some quick face saving footwork by

diplomats. France, Germany and Italy have so far refused to endorse an increase in EEC's food aid from 1.3 million tons to 1.6 million tons. This was bitterly attacked in Rome, not the least by UK which threatened to increase its own bilateral aid if the insensitivity of its partners continued. The commitment to 10 million tons — even though well short of food aid levels of 1960 — has still not been reached."

Is there a real absolute overall shortage of food in the world, which makes the contribution of this 10 million tons impossible — and with this the inevitability of starvation in poor countries? The answer is No.

It should be emphasized again and again that the grain is physically available. It is simply being consumed by well-fed people. Since 1965, the richer nations have added 350 pounds per head to their annual diets, largely in the form of beef and poultry. This was stimulated by a special pricing policy at a time when US surpluses of food grains were running in excess of world demand by some 60 million tons a year, in spite of a curtailment in area cropped, by one half. This is very nearly the equivalent of an Indian's total diet for a whole year. Few will maintain that the industrialized countries were under-nourished in 1965. A cut in consumption, for example the suggested equivalent of one hamburger a week, could provide all the grain needed to support a population as large as one third of the Indian sub-continent.

Let us next consider the question of armaments; and arms reduction. In 1973 the world military expenditure came to 245 billion dollars. This sum is 163 times greater than that spent on international co-operation for peace and development through the United Nations system; (this sum stands at approximately 1.5 billion, excluding the World Bank). The super powers spent 50% of these 245 billion dollars, while another 30% was spent by military alliances. The share of the Third World also, unfortunately, increased between 1955 to 1975 from 6% to 17% — and we are not entirely blameless. The world military expenditures are now greater than the GNP of all of Africa and all of South Asia. During the two decades, 1960's and 1970's the total military expenditure was $4,000 billion, which is greater than all goods and services produced by all mankind in one year.

When we consider the situation with materials and men, the situation regarding military expenditures appears even grimmer. Close to 7% of all raw materials in the richer countries are consumed by the armament industry. This includes oil, iron, tin, zinc, copper and bauxite. It is estimated that about 50 million people are employed for military purposes in armed forces and defence activities. Close to half a million scientists and engineers, almost half of the world's scientific and technological manpower, is devoted to military research and development, costing between \$20 to \$25 billion. These sums represent 40% of all public and private research and development expenditure mankind appropriates. Contrast this with the half million dollars we have been able, after five years of continuous effort, to collect for the International Foundation for Science whose first General Assembly is taking place in Stockhom today. The situation is clear, it is not the poor countries who jeopardize the global balances, it is the rich and their rivalries and their desire to hold monopoly military power.

To summarize, the demand for a New International Order is a demand of a basic minimum standard of living and of economic security for all citizens; a deliberate policy of development and redistribution to achieve this. Just as on a national scale the achievement of the social and economic goals is left not entirely to individual effort and initiative but is prompted actively by the combined efforts of the entire community, so also on an international level the aspirations of the nations of the world in the social and economic sphere should be made easier to achieve by a concentrated effort of the world community as a whole — by the Family of Man, acting as a whole.

What the developing countries really want on a psychological plane is to regain their sense of dignity and self respect which they enjoyed for long centuries and which they lost only during the brief period of western domination; a domination based essentially on an industrial and techological revolution which is hardly two centuries old. The fact that country after country in all parts of the world has successively and successfully mastered technology is also not overlooked by those who are still left behind. What the developing countries are asking

for is not unlimited migration, to the open, uncultivated, under-utilised areas of this globe; they have never asked for transfer of income, wealth and resources at any exorbitant level. It is rather a meaningful sharing of technology and equitable trade they are really after.

Perhaps the time has come for supplementing national transfers with some international sources of revenues — the international commons, taxed for the benefit of the poorest strata of poor countries. This would be a first step towards the establishment of an international taxation system and an international treasury aimed at providing automatic transfers of resources for development assistance. I remember this suggestion being voiced by Linus Pauling at the 1969 Noble Symposium on the Place of Value in a World of Facts, held in Stockhom in 1969 and the somewhat cool reception the idea received. It appeared too radical at that time. But perhaps its time has come; perhaps one may start with an international commons provided by resources of world oceans, the one resource not yet finally carved out among nation states.

Oceans

The 138 Nation Law of the Sea Conference held in Caracas, Venezuela in 1974 has negotiated at its last session in Geneva a single informal negotiating text which fortunately is still subject to amendment. The comprehensive treaty envisaged for 1975 has been called the most vital document the United Nations will produce, since 1945. The treaty envisages extension of territorial waters from 3 to 12 nautical miles, an exclusive economic zone under coastal state jurisdiction extending up to 200 miles, plus 200 metres depth whichever is farther. This, if finally approved, would be an unmitigated disaster, even though some developing countries will benefit from this. The sea bed contains perhaps 1,500 billion barrels of petroleum; at present some 15% of the world's oil and gas comes from the oceans, but they contain perhaps the major portion of future oil potential. Some 18 billion dollars of high protein fish are caught annually and then there is the possibility of easy dredging from the North Pacific deep ocean-floor of some 400 million tons of cooper, manganese, nickel and cobalt nodules every year. Compare this 400 million tons with 10 million of these

minerals consumed annually now. The exciting thing about these nodules at the ocean bed is that they obligingly renew themselves all the time—either because they are organic materials like coral or because some obscure process of ionization is at work at the sea bed.

The effect of the proposed treaty will be to place 62% of the sea bed oil under the jurisdiction of 10 of the most fortunate coastal states—most of which have per capita incomes already exceeding $1,000—while 51 countries with little or no continental shelf will get only 1%. I am no legal expert, but to any internationalist it is clear that what is truly needed is the replacement of the outmoded concept of national sovereignty by a concept of "functional sovereignty" which permits the inter-weaving of national and international jurisdiction within the same territorial space. At present, the only agreement which has been reached envisages that there will be an International Sea Bed Resources Authority which will provide environmental protection over deep sea mining and that it might be allocated revenues collected directly from production of deep sea minerals. However, regarding the more immediate resource, oil, there is still a discussion going on, if royalty revenues from sea bed oil may be pooled through an international fund, to be used primarily for developing countries. Canada has suggested collection of 1% of sea bed oil revenue. The US Government suggests a small percentage of revenue from oil *beyond* 200 miles limit. But there is no foreceful voice, yet, calling for a significant reapportioning of these new windfalls such that a meaningful international commons is paid—for global development.

This trend of thinking must be reversed. Substantial revenues from sea bed oil could go to the international community. Twenty percent of these could provide a sum for developing countries of up to as much as 6-12 billion dollars a year. The International Sea Bed Resources Authority could become a model for world institutions, dealing with arms control, disarmament or global resource management. Geneva 1975 may be the last and the only opportunity of ensuring that the concept of "common heritage of mankind" becomes and remains—not just an empty concept.

I should perhaps conclude by telling you what actually happened at the United Nations Conference. What is it that has been achieved? Dr. Henry Kissinger, alive to the danger of a war confrontation more virulent, more destructive than any cold war urged the recognition that if there was no action on the demands from the poor: "Over the remainder of this century...the division of the planet between north and south could become as grim as the darkest days of cold war. We would enter an age of festering resentment, of a resort to economic warfare, a hardening of new blocks, the undermining of cooperation, the erosion of international institutions—and failed development."

Dr. Kissinger and the US have promised a multiplicity of institutions to meet the needs of co-operative world development. Two of these are:

(1) A "Development Security Facility" to stabilise prices of commodities against crude cycles of export earnings though "indexing" was decisively ruled out;

(2) Measures to improve access to capital technology and managerial skills—and in particular an International Energy Institute, an International Centre for Exchange of Technological Information and an International Industrialization Institute.

At long last the physicists we have trained at Trieste will find a rightful role in the development of their countries, though I do hope these new Centres do not suffer the frustrations which 11 years of running a United Nations institute have taught me to fear. In dealing with the United Nations one finds to one's frustration that the promises which one department of a national government makes go unneeded by the other departments of the same Government; that each department of each donor country wishes to investigate *ab initio* what the United Nations Centre is achieving. So far as Trieste is concerned, this year there have been five commissions reporting on the Centre; there will be two more before the year ends. And this happens every year. The point is that the United Nations funds are extremely limited, the organization is an orphan and the energy needed to keep any initiative alive through the United Nations is often out of all proportion to the results achieved.

To come back to the Conference, regretfully there was no new commitment of resource transfers—these new institutions

will presumably divide the old cake differently; their very multiplicity will unfortunately not make any realization of the ideals of world development any easier.

I come back to you—my audience—you are our only hope to realize the ideals I spoke of into realities in a meaningful manner. For make no mistake, for world development much sacrifice will be called for and will have to be made. But I am a believer in man's moral state and I shall conclude with the words of a mystic who expressed the international ideal of Family of Man in the 17th century, John Donne: "No man is an island, entire of itself; every man is a piece of the continent, a part of the main; if a clod be washed away by the sea, Europe is the less, as well as if a promontory were, as well as if a manner of thy friends or of thine own were; any man's death diminishes me, because I am involved in mankind; and therefore never send to know for whom the bell tolls; it tolls for thee."

TABLE I

BUDGET FIGURES (in millions US $)

	1975	1976
UN	540	620
UNEP	6	6
UNIDO	31	45
IAEA	32	37
WHO	115	125
UNESCO	255 (including 100 from UNDP)	—
ILO	94	135
FAO	117	(unavailable)
ICAO	12	13
IMCO	(unavailable)	11

TABLE II

Table of Grain Surpluses and Deficits—1973 (in million tons of grains)

North America	+91
Latin America	— 3
Asia	—43
Africa	— 5
East Europe	—27
West Europe	—19

9. Salam's Paper on "Renaissance of Sciences in Arab and Islamic Lands", dated March 1981.

RENAISSANCE OF SCIENCES IN ARAB AND ISLAMIC LANDS

Contribution prepared for the United Nations University Symposium on Scientific Creativity in Arab and Islamic countries (Kuwait, March 1981).

I solemnly declare that there is no god except Allah.
I (also) solemnly declare that Muhammad is His slave and His Messenger.

In the name of God, Most Gracious, Most Merciful.

I deeply appreciate the honour done to me by asking me to speak at this Symposium. Although what I have to say applies to many developing countries, including my own, I can say it with intense feeling here, and without fear of being misunderstood. This is because I can claim with you in Kuwait the kinship of Islam, which transcends all other kinships. For this I invoke Blessings of Allah on His Prophet.

The major theme of my remarks today is Pure Science. I have come to plead with you for giving the highest priority to the creation of knowledge within a scientific commonwealth of Arab and Islamic nations, and to outline the steps needed if we are to take up our rightful self-respecting place among the comity of nations in this regard. But before I speak on this I shall take a few minutes to mention some of the developments in particle physics, particularly those concerning the fundamental forms of Energy, and natural forces, with which I have been associated.

Unification of Fundamental Forces

Until two decades ago, physicists believed that there are four fundamental forms of energy; the gravitational energy, the electromagnetic energy and the two forms of nuclear energy, the so-called weak and the strong. Now it is commonplace that all these forms of energy can be made to interconvert: the gravitational, for example, into the electric. Hydro-

electricity is a manifestation of this. Or the strong nuclear energy produced in the sun's interior, converting into the electro-magnetic energy of heat of the sun's rays. Two decades ago, my colleagues and I suggested that there were indications that the weak nuclear form of energy was basically simply identical with the electromagnetic. This was not just a matter of inter-conversion of one form of energy into the other; our result went deeper. In our view, there should be no basic distinction between electricity and nuclear forces. We said they were simply identical. We suggested that under suitable conditions in the laboratory this identity, normally hidden, could be made manifest.

The first indication of the theory's correctness came in 1973, when the great European Nuclear Research Laboratory at Geneva (CERN) found experimental evidence of neutral currents which are an essential part of the predictions of the theory. The clinching evidence was provided in 1978 by the Stanford Linear Accelerator in the United States which, in an epic experiment, confirmed its second aspect—its heart, as it were—of the unification of the electromagnetic force with the weak nuclear to one part in four thousand as predicted. An experiment at Novosibirsk by a group led by Professor Barkov further confirmed this. To these and to other great laboratories situated in Europe, the United States and the USSR, I wish to express my appreciation for the remarkable series of experiments which have now confirmed that the weak nuclear force is indeed basically the same as the electro-magnetic.

The next task is to test if the third form of energy (the strong nuclear) is also part of this unity. Together with some colleagues, we have formulated this and suggested experiments to test the idea. These experiments have started in the U.S., in Europe and India. If the results are positive, in about three years, with Allah's grace, we shall have demonstrated that all *nuclear* force—and not just the *week* nuclear—is identical with the *electric* force which binds an atom together.

Then will remain the final goal of uniting the gravitational force with the newly recognized electro-nuclear force. The epitome of this (unity) وحدت will be to find that the force which makes an apple fall or which keeps the moon in its

orbit—the force of gravity—is an aspect of the same unity of which the electric force or the nuclear forces are part. This sounds incredible today, but it is our faith that this must also be true. A precise formulation and the confirmation of this idea—first suggested by Einstein—may take 50 years to achieve. Let me hope and pray that this final challenging problem is resolved by a young future physicist from the lands of Islam.

The fact that we have been seeking for a unity among the seemingly disparate forces of nature, is part of our faith as physicists and of mine as a Muslim. And to be thus privileged to comprehend a part of Allah's design is a grace and a privilege for which I render humble thanks to Allah.

Al-Hadid

21 — Race one with another forgiveness from your Lord and a Garden whereof the breadth is as the breadth of the Heaven and the earth, which is in store for those who believe in Allah and His messengers. Such is the bounty of Allah, which He bestoweth upon whom He will, and Allah is of infinite bounty.

Al-Jumuah:

4 — Such is the Bounty of God which He bestows on whom He will and God is the Lord of the highest bounty.

On the occasion of the Prize ceremony in December 1979, I was asked to reply on behalf of the Physics Prize Winners to the Banquet address of His Majesty the King of Sweden in the great and glittering Banqueting Hall of Stockholm. With your indulgence, I shall read out part of what I said, for it bears on this faith in the ultimate unity and symmetry of Nature.

"The creation of physics is the shared heritage of all mankind. East and West, North and South have equally participated in it. In the Holy Book of Islam, Allah says:

Al-Mulk:

3 — Who hath created seven heavens in harmony. Thou (Muhammad) canst see no fault in the Beneficent One's creation; then look again: Canst thou see any rifts?

4 — Then look again and yet again, thy sight will return unto the weakened and made dim.

'Thou seest not, in the creation of the All-Merciful any imperfection. Return thy gaze, seest thou any flaw. Then

return thy gaze, again and again. Thy gaze, comes back to thee dazzled, aweary.'

This, in effect, is the faith of all physicists, the faith which fires and sustains us; the deeper we seek, the more is our wonder excited, the more is the dazzlement for our gaze.

I am saying this, not only to remind those here tonight of this, but also for those in the Third World, who feel they have lost out in the pursuit of scientific knowledge, for lack of opportunity and resource.".

Science the Shared Heritage of Mankind

To emphasize that science is the shared heritage of mankind, and that the history of scientific discovery, like the history of all civilization, has gone through cycles, I recalled in my Nobel lecture a historical episode, when, some seven hundred and sixty years ago, a young Scotsman left his native glens to travel south to Toledo in Spain. His name was Michael, his goal to live and work at the Arab universities of Toledo and Cordova. Michael reached Toledo in 1217 A.D. Once in Toledo, Michael formed the ambitious project of introducing Aristotle to Latin Europe, translating not from the original Greek, which he knew not, but from the Arabic translation which was then taught in Spain. From Toledo, Michael travelled to Sicily, to the Court of Emperor Frederick II. Visiting the medical school at Salerno, chartered by Frederick in 1231, Michael met the Danish physician, Hendrik Harpestraeng — later to become Court Physician of King Eric IV Waldemarsson. Hendrick the Dane had come to Salerno to compose his treatise—preserved in seven volumes at the National Library in Stockholm—on blood-letting and surgery. Hendrik's sources were the medical canons of the great clinicians of Islam, Al-Razi and Avicenna, which only Michael the Scot could translate for him.

The Schools of Toledo and Salerno mark the beginning of creation of Sciences in the West. At these schools a candle was lighted from a candle already burning brightly in the lands of Islam.

In respect of this cycle of scientific creation, perhaps I can be more quantitative. George Sarton, in his monumental five-

volume History of Science, chose to divide his story of achievement in sciences into ages, each age lasting half a century. With each half century he associated one central figure. Thus, 450-400 B.C., Sarton calls the Age of Plato; this if followed by half centuries of Aristotle, of Euclid, of Archimedes, and so on. From 600 A.D. to 700 A.D. is the Chinese century of Hsiian Tsang and I Ching and then from 750 A.D. to 1100 A.D.—350 years continuously—it is an unbroken succession of the Ages of Jabir, Khwarizmi, Razi, Masudi, Wafa, Biruni and Avicenna, Ibn-al-Haitham and Omar Khayam—Arabs, Turks, Afghans and Persians—men belonging to the culture and the Commonwealth of Islam. After 1100 A.D., in George Sarton's *Story of Sciences*, appear the first Western names; Gerard of Cremona, Roger Bacon—but the honours are still shared for another two hundred and fifty years with the names of Ibn-Rushd, Nasir-ud-din, Tusi and Ibn-Nafis—the man who anticipated Harvey's theory of circulation of blood.

After 1350, however, the Islamic world loses out except for the very occasional flash of scientific brilliance, like that at the Court of Ulugh Beg—the grandson of Emir Timur—in Samarkand in 1437 A.D., with Emir Ulugh Beg himself participating equally with his astronomers in scientific debate and sharing in the excitement of discovery. And finally there is the compilation of Zijj Muhammad Shahi at the Court of the Moghul Emperor of Delhi in 1720, which corrected the best European tables of that day by as much as 6′ of arc. But these contributions notwithstanding, the main scientific tradition was no longer alive and vigorous; long, long before it had turned inwards and ossified.

And this brings us to this century when the cycle begun by Michael the Scot turns full circle, and it is we in the Islamic and Arab woild who turn Westwards for stimuli in scientific creation

Eleven hundred years ago Al-Kindi wrote: "It is fitting then for us not to be ashamed to acknowledge truth and to assimilate it from whatever source it comes to us. For him who scales the truth there is nothing of higher value than truth itself; it never cheapens nor abases him who seeks." Al-Kindi was right—truth is truth wherever it is discovered. Yet how can I convey to you the very human urge Allah has given all of us

to be among those privileged to discover of His design, of the prayer He has taught us to recite:

Let me recall just one human moment of scientific history; the story of Hans Bethe, the Nobel Laureate in Physics for 1967. The day he discovered the carbon cycle which explains the secret of the colossal energy production of stars, and for which he was awarded the Prize, Bethe and his wife were staying in a desert location in New Mexico. During the starry desert night Rose Bethe recalls remarking to her husband how bright the starts in the firmament were. Bethe replied: "Do you realize, just now you are standing next to the only human who knows why they shine at all.".

The Decline of Science in Islam

But why did we in Islamic lands lose out? No one knows for certain. There were indeed external causes, like the devastation caused by the Mongols, but, grievous though it was, it was perhaps more in the nature of a temporary interruption. Sixty years after Ghengiz, his grandson Halagu was founding an observatory at Maragha. In my humble view, the demise of living science within the Islamic Commonwealth was more due to internal causes. I shall not analyze these here today. But to illustrate the apathy that had come over us I shall quote from Ibn-i-Khaldun, one of the greatest social historians and the brightest intellects of all times, who wrote one hundred and seventy years *after* the journeys which Michael the Scot and Hendrik the Dane had undertaken to acquire knowledge from the World of Islam. Ibn-Khaldun writes in his *Muqaddima:* "We have heard, of late, that in the land of the Franks, and on the northern shores of the Mediterranean, there is a great cultivation of philosophical sciences. They are said to be studied there again and to be taught in numerous classes. Existing systematic expositions of them are said to be comprehensive, the people who know them numerous and the students of them very many.... *Allah knows better, what exists there*, but it is clear that the problems of physics are of no importance for us in our religious affairs. Therefore, we must leave them alone." Ibn-i-Khaldun displays no curiosity, no wistfulness, just apathy, bordering almost on hostility. This

apathy led to isolation. The tradition of Al-Kindi, of acquiring knowledge from wherever it could be obtained, was forgotten; the Muslim world of science sought no contacts with the West where sciences had now begun to be created. Five centuries before Muslims had avidly sought knowledge, first from the Hellenic and Nestorian colonies or scholars at Jundishapur and Harran, where translations were made from Greek and Syrian. Then they had founded in Baghdad, Cairo and elsewhere international institutes of advanced study—*Bait-ul-Hikmas*— and international observatories—the *Shamsiyyas*—congregating at these international concourses of scientists from all lands. Such concourses had begun to be assembled, scientifically developed and sedulously cultivated, starting with research establishment of Sagres set up in 1419 by Prince Henry the navigator. And even while envying and trying to acquire the technologies involved, we failed to understand the basic interrelation between Science and Technology. As late as 1799, when Selim III did introduce modern studies of algebra, trigonometry, mechanics, ballistics and metallurgy into Turkey, importing French and Swedish teachers, in order to rival the European arts of gun-founding, he failed to place emphasis on basic scientific research in these subjects, so that Turkey never caught up with Europe. Thirty years later, Muhammad Ali in Egypt had his men trained in the arts of surveying and prospecting for coal and gold mines, but it did not strike him or his successors to train Egyptians long-term in the basic sciences of geology. And even today, when we have come to recognize that Technology is the Sustenance and the Power, we have not appreciated that there are no short cuts to it; that basic science and its creation must become part of our civilization, as a precondition of a mastery of science in application. If one was being Machiavellian, one might discern in the slogan "Technology without Science" sinister motives among those who have sold us this idea.

To underline this, let me give just one quotation from a recent issue of the prestigious London *Economist* of 27 September 1980, writing on the cherished mastery of solar energy: "If solar energy is to provide the solution to the world's fuel crisis, that solution will not emerge from low-technology roof-top radiators—(which) rely on

Nineteenth century (science). A breakthrough (will) come from applying quantum physics, biochemistry or other sciences of the Twentieth Century. Today's technology-based industries all depend on new science."

Pre-conditions for a Renaissance of Sciences in Islam

The reason why the Muslims searched for and developed sciences—in their Golden Age in the 8th, 9th, 10th and 11th centuries—is not hard to seek. The Muslims were following the repeated injunctions of the Holy Book and the Holy Prophet (peace be upon him). According to Dr. Mohammad Aijazul Khatib of Damascus University, nothing can emphasize the importance of science more than the remark that: "In contrast to 250 verses which are legislative, some 750 verses of the Holy Quran—almost one eighth of it—exhort the believers to study Nature—to reflect, to make the best use of reason and to make the scientific enterprise an integral part of the Community's life.".

I do not have to remind this audience of the proud title of the "Inheritors of the Prophets" which the Holy Prophet (peace be upon him) accorded to the علماء , the men of science and knowledge. In this context let me remind you that in the Arabic language there is no word except "*ilm*" for Science.

The Holy Quran emphasizes the superiority of the عالم , the man possessed of science and knowledge:

Al-Zumar:

9 — Is one who worships devoutly during the hours of the night prostrating himself or standing (in adoration), who takes heed of the Hereafter, and who places his hope in the Mercy of his Lord — (like one who does not)? Say: "Are those equal, those who know and those who do not know? It is those who are enduced with understanding that receive admonition.

It was indeed these exhortations of the Holy Book which made the whole society in Islam scientifically conscious.

A crucial aspect of this veneration was the patronage extended to the creation of Sciences in the Islamic-Arab Commonwealth. To paraphrase what H.A.R. Gibb has written about Arabic literature to the parallel situation for Sciences: "To a

greater extent than elsewhere, the flowering of Sciences in Islam was conditional .... on the liberality and patronage of those in high positions. Where Muslim society was in decay science lost vitality and force. But so long as in one capital or another princes and ministers found pleasure, profit or reputation in patronising sciences, the torch was kept burning." This was true, by and large, up to the 14th century. Later this patronage has lost; symbolic of this was the episode of the blasting of the Observatory at Istanbul by naval ordnance on the orders of Murad III—recorded in almost jubilant verse by Ala-ud-din Mansur, the court poet, in the 16th century—on the grounds that the observatory's task of correcting the astronomical tables of Ulugh Beg had been accomplished. It was needed no more. And then after this, there was unchecked decline even so that William Eton, the British Consul to the Ottoman Empire would write in the year 1800: "No one has the least idea of navigation and the use of the magnet...Travelling, that great source of expansion and improvement to the mind is entirely checked by arrogant spirit of their religion and...by the jealousy with which intercourse with foreigners...is viewed in a person not invested with an official character...Thus the man of general science...is unknown: anyone, but a mere artificer who should concern himself with the founding of cannons, the building of ships or the like, would be esteemed little better than a madman." He concludes with the remark, with an ominous modern ring: "They like to trade with those who bring to them useful and valuable articles, without the labour of manufacturing."

Can we turn the pages of history back and once again lead the world in Sciences? I would humbly like to submit that we can—provided society as a whole, and our youth in particular—come to accept this as a cherished goal. In keeping with our own experience of earlier centuries and the experience of others, we must remember that there are no short cuts. In the conditions of today a nation's youth have to be fired for it and the nation commit itself with a passionate commitment; it must impart *hard* scientific training to more than half of its manpower; it must pursue basic and applied sciences with 1-2% of its GNP spent on research and development; at least one tenth of this on pure sciences alone. This was done in Japan with the Meiji

revolution when the Emperor took an oath that knowledge will be acquired from wherever it can be found from the far corners of the earth. This was done in the Soviet Union sixty years ago when the Soviet Academy of Sciences, created by Peter the Great, was asked to expand its numbers and set the ambition of excelling in all sciences. Today it numbers a self-governing community of one million scientists working in its institutes, with priorities and privileges accorded to them in the Soviet system that others envy. And this is what has been undertaken today in a planned manner at a frantic speed by the People's Republic of China, with a defined target of catching up and surpassing the United Kingdom in high energy physics, in space sciences, in genetics, in micro-electronics, in fusion physics and in control of thermo-nuclear energy. The Chinese have recognized that all basic science is relevant science; that the frontier of today is tomorrow's application and that they must remain at the frontier. In this context one may recall that the GNP of the Islamic-Arab nations exceeds that of China, while the human resources are not significantly smaller. And China has a lead of no more than a few decades over us in Sciences. Shall we set ourselves the goal, at the least, of emulating the Chinese?

I have spoken earlier of patronage for Sciences. One aspect of this is the sense of security and continuity which a scientist-scholar must be accorded for his work. Today, an Arab or a Pakistani scientist and technologist—and there are more than thirty thousand of them—can be sure of life-long welcome in the United Kingdom or the United States if he possesses the requisite quality. He will have security, respect and equality of opportunity for his work and advancement. We must ask ourselves if this is true within our societies. We must ask ourselves if we discriminate against, or even at times terminate the services of scientists because they happen to have originated in a country with which our government may temporarily have differed.

I have spoken throughout this lecture of a Commonwealth of Science for the Islamic and the Arab countries, even if there may be no political commonwealth of these countries yet in sight. Such a Commonwealth of Science was a true reality in the great days of Islamic Science, when the great Central Asians

like Ibn-Sina and Al-Biruni would naturally write in Arabic, or their contemporary and my brother in physics, Ibn-ul-Haitham could migrate from his native Basra in the dominions of the Abbasi Caliph to the Court of his rival, the Fatmi Caliph, Al-Hakim, sure of receiving respect and homage, notwithstanding the political and sectarian differences which were no less acute then than they are now. This Commonwealth of Science needs conscious articulation, and recognition once again, both spiritually and physically, both by us, the scientists as well as our governments. Today we, the scientists from the Islamic and the Arab countries, constitute a very small community—one hundredth to one tenth in size, in scientific resources, and in scientific creativity compared to international norms. We need to band together, to pool our resources, to feel and work as a community, as is indeed happening in practice. To foster this natural growth, could we possibly envisage from our governments a moratorium, a compact conferring of immunity, for say the next twenty five years, during which the scientists from within this Commonwealth of Science, this *Ummat-ul Ilm*, could be treated as a special sub-community with a protected status, so far as internal political and sectarian differences are concerned, just as was the case in the Islamic Commonwealth of Sciences in the past?

And finally, there is the isolation of our scientific effort from international science. It is amazing to find that with the exception of Egypt, which is a member of sixteen Unions, no other Arab or Islamic country uniformly subscribes to more than five International Scientific Unions in the diverse subjects of science. No international centres of scientific research have been created or are located within our confines; few international scientific conferences are organized there; very few of us, if living and working in our own countries, are privileged to travel to scientific institutions and meetings outside; such travel as a rule, is considered wasteful luxury. The situation is a little better in Arab OPEC countries; it is dismal in non-Arab Islamic lands. It was this isolation which forced me to leave my country twenty-five years ago, after teaching there a number of years. I had a stark choice: either to remain in Physics or in Pakistan. With anguish in my heart I left. And this is what prompted me to propose the creation of an International Centre

for Physics in Trieste, so that others in my position do not have to make that agonising choice. This Centre belongs to two United Nations Agencies—IAEA and UNESCO; one hundred Arab and Muslim physicists are supported at the Centre every year, with funds for them originating, sadly, not from the Arab and Islamic sources, but by and large from the U.K., from Italy and Sweden.

And it is not just the physical isolation of the individual scientist that we suffer from. There is also the isolation from the norms of international science, the gulf between the way we run the scientific enterprise in our countries and the self-governing manner it is run in the West or within the community of scientists in the USSR Academy. We seem to have no developed system of professional organizations, no internal review committees, no independent studies of state of art or quality, no science foundations administered by the scientists, no independent sources of grants.

To summarize, the renaissance of Sciences within an Islamic and Arab Commonwealth is contingen. upon five cardinal preconditions: passionate commitment, generous patronage, provision of security, self-governance and internationalization of our scientific enterprise.

Technology in Our Countries

And this finally brings me to Technology, with the Holy Book of Islam placing equal emphasis on تسخیر (*Tashkir*) as on تفکر (*Tafakkur*)—on acquiring mastery of nature, through scientific knowledge as much as on the creation of knowledge. The Holy Book holds forth for us the examples of David and Solomon, with their mastery of the technologies of their day. "And we made iron soft for him..." "We subjected the winds for him" and "under his command he had *jinns*...", that is, in my humble interpretation, controlled powers of the heavy machinery of the day, which fashioned building blocks, palaces, dams and reservoirs. And then we are reminded of *Dhul-qarnain*, building defences with blocks of iron and molten copper. Thus are the technologies of metallurgy, heavy construction, technology of wind-power and of communications emphasised. As every Muslim knows, the Holy Book does not

relate, except as an exhortation for the future and as an example to be followed by the community.

Al-Hashrc

21 — If We had caused this Qur'an to descend upon a mountain, thou (O Muhammad) verily hadst seen it humbled, rent asunder the fear of Allah. Such similitudes coin We for mankind that haply they may reflect.

But what are the obstacles in our societies to our acquiring the highest proficiency in technology? After all, never before in human history has so much effort and such magnitude of funds gone into creating technical facilities in such a short duration of time as in the Arab lands during the last decade. Thus, according to Zahlan, by 1978 more than 400 billion dollars will have been spent on major technological contracts between Arab countries and foreign suppliers. These projects range over hydrocarbons and petrochemicals (160 billions) civil works including transport (80 billions), industrial plant including iron and steel, pharmaceuticals and fertiliser plant (40 billion).

Unfortunately, most of these projects have been executed in the technology-free turnkey mode; their execution has had no association, no employment of the incipient research and development community of Arab men of technology and engineering. And one of the reasons has been the fragmentation of the projects. Thus, according to Zahlan, the 584 projects executed by 1976 in the field of petrochemicals, were designed by 83 international firms. The projects included 16 for urea plants; of these: Algeria had 1, Egypt 1, Iraq 2, Kuwait 4, Libya 1, Qatar 2, Saudi Arabia 1, Sudan 1, Syria 1, and UAE 1. No Arab country or combination of countries in the entire Arab Commonwealth had—or now has—the technical base to provide the design and construction services for these projects, nor the competence to upgrade these and modify them if need arises. As contrasted with this, consider Japan with a population nearly equal in size to the Arab nations, and which entered the field of petrochemicals machinery twenty years ago. Right from the outset the Japanese had made up their minds to export such machinery; thus, during the last twenty years every third Japanese plant has been exported. The Japanese had the

will as well as the competent men. The situation is no different in other non-Arab Islamic countries, except that relatively the sums involved are smaller, and the number of projects executed fewer.

What is the reason for lack of attention to the concept of attaining future self-sufficiency in manufacture? The answer is uniformly the same: the decision maker is as a rule a non-technical person; our countries at best are the paradise of the planner, the administrator; the technologist has no part in decision making. In Pakistan, the Planning Commission does not have a science and technology cell. Even worse, inheriting a tradition from the British Indian Civil Service, it is assumed that a technologist is incapable of taking any but specialized decisions; his is not the broad vision; he has no training for such a job. We seem not to have noticed that, in Japan, in China, in Korea, in Sweden, in France—in all the countries with successful records of self-reliant growth—the completest accord, participation and involvement exists between the scientist, the technologist, and those who run the development machinery of the state and the industry, with full trust in each other's sphere of work.

Besides industrial and science-based technology, there is the whole area of science in application, in agriculture, in public health, in biotechnology, in energy systems, and in defense. The story in all these spheres is the same. I remember hearing the late Lord Mountbatten once give a lecture to the Royal Society. He was narrating his experience during the war in working with scientists like Sir Solly Zuckerman and the future Nobel Laureate, Lord Blackett. Lord Mountbatten recalled that at the first meeting with the scientists in 1939, he presented to them a list of war problems which the Services had specified for the scientists to solve. Mountbatten recalled Sir Solly Zuckerman simply laughing at the presentation of the list, saying: "Please do not specify what *you* think are the problems. Take us into your confidence; tell us your *objectives* and let us define in our own manner the obstacles and the problems. We shall then jointly endeavour to find solutions to meet the precise objectives you have set up.".

The Two Appeals

Why am I so passionately advocating our engaging in this enterprise of creating knowledge? This is not just because Allah has endowed us with the urge to know, this is not just because in the conditions of today knowledge is power and science in application the major instrument of material progress; it is also that as members of the international world community one feels that lash of contempt for us—unspoken but still there—of those who create knowledge.

I can still recall a Nobel Prize Winner in Physics some years ago from a European country say this to me: "Salam do you really think we have an obligation to succour, aid and keep alive those nations, who have never created or added an iota to man's stock of knowledge?" And even if he had not said this, my self-respect suffers a terrible hurt whenever I enter a hospital and find that almost every potent life-saving medicament of today, from penicillin upwards, has been created without our share of inputs from any of us in the Third World, or from Arab lands or from Islam.

I wish to conclude with two appeals—one to my fellow scientists both those inside our countries and those outside them; and the second to our rulers and our administrators. First to my brothers, the scientists. We have rights, as well as obligations. We are few in number, the sizes of our communities are individually sub-critical. This, however, is not so if we band together in an *Ummat-ul ilm*. The building up of such a truly Islamic Commonwealth and the renaissance of Sciences in it depends on us, in the last analysis. For all our quantitative weakness, let us not be the less ambitious, at least as far as quality is concerned, of which there is no dearth whenever opportunities present themselves. I repeat to you what Jamal Abdul Nasser said:

"Raise your head in pride and self-esteem."

When I joined Cambridge as an undergraduate in 1946 I was older than my contemporary British students. I knew more science than they did. But they possessed an arrogance from belonging to the nation of Newton, Maxwell, Darwin, Dirac.

Recall that in your past, too, there are men like Ibn-al-Haitham, Ibn-Sina, Al-Biruni. Assume that you will be given all the facilities all the resources, you want for Pure and Applied Science. Assume that your applied researches will be utilised. Assume that you will have self-governance within your communities and involvement in your society's plans of development. For those outside, assume that you will be called upon to play your designate roles in bringing this renaissance of Sciences about. And then make audacious plans for your institutions and projects and programmes for the joint Islamic Commonwealth of Science. To mark this ambition and speaking for my own sub-discipline of physics, if China—with a smaller GNP than our countries, and with a scientific lead of no more than a few decades—can contemplate joining the league of the USA, of combined Europe and of the USSR in building the world's fourth largest high-energy accelerator, ahead of Japan; if it can project joining the world Tokamak Fusion Reactor Project, INTOR, expected to produce fusion power in 15 years and costing 1.5 billion dollars; if the Chinese scientists can build the world's most sensitive gravitational-wave detecting devices—as they had done in 1978—simply from reproducing the published descriptions of these in the *Physical Review*; if India, with a GNP considerably smaller than ours, can project radio telescopes, cosmic ray arrays, and now collaborating with Japan, the first deep underground experiment for proton decay—a project in which I personally rejoice—I do not see any reason why our Commonwealth of Sciences should not also contemplate mounting physics as well as physics-based technological projects on the same scale within its confines. I do not see why the lands of Islam should not have the most prestigious institutes in our subject—Mathematics. If our own manpower is presently short, let such projects hosted by us be thrown open to research collaborations internationally. We will be the ones to benefit from this, besides paying our due debt back to international science. In the same vein, I would like our countries to join, as full or associate members, international enterprises like the fusion INTOR and international Earth Watch projects of ICSU. If Greece, with one tenth of the GNP of Arab countries, and with scant resources in Physics manpower, can aspire to

join as a full member the European Organization for Nuclear Research in Geneva, for an accelerator project which will cost ½ billion dollars, designed to produce in the laboratory the heavy photons which our unified theory predicts, I do not see why the Turkish-Arab-Islamic aspiration should be the inferior. With ambition, and with involvement will come competence, for this is Allah's promise to all those who strive.

AL-e-Imran

195 — And their Lord hath heard them (and He saith): Lo. I 'suffer not the work of any worker, male or female, to be lost. Ye proceed one from another. So those who fled and were driven forth from their homes and suffered damage for My cause, and fought and were slain, verily I shall remit their evil deeds from them and verily I shall bring them into Gardens underneath which rivers flow — A reward from Allah. And with Allah is the fairest of reward.

And now finally I wish to appeal to those responsible for our affairs: science is important because of the underlying understanding it provides of the world around us and of Allah's design; it is important because of the material benefits its discoveries can give us and finally because of its universality, it is a vehicle of co-operation of all mankind and in particular for the Arab and Islamic nations. We owe a debt to international science, which in all self-respect, we must discharge. However, the scientific enterprise cannot flourish without your generous patronage as in the past centuries of Islam. The international norms of one to two per cent of GNP, would mean expenditures of the order of two to four billion dollars annually for the Arab and the same amount for the Islamic world on research and development, one tenth of this spent on pure science. We need science foundations in our countries, run by the scientists, international higher centres of learning within and without our universities, providing generous support, security and continuity, for men and their ideas. Let no future Gibb record that in the fifteenth century of the Hijra the scientists were there but there was a dearth of princes with their generous patronage.

AL-e-Imran

194 — Our Lord. 'And give us that which Thou has promised to us by Thy messengers. Confound us not upon the Day of Resurrection. Lo.' Thou breakest not the trust.

10. Salam's Paper on "The Nature of the Ultimate Explanation in Physics", dated 12 November 1979 (Technical Paper).

"Experiment alone can decide on truth"...."But the axiomatic basis of physics cannot be extracted from experiment.".

—Einstein, *Herbert Spencer Lecture*, June 1933.

Sec. 1. All science—physics in particular—is concerned with discovering WHY things happen as they do. The WHYs so adduced must clearly be "deeper", more universal, more axiomatic, less susceptible to direct experimental testing, than the immediate phenomena we seek to explain. And it is also well-known, that it is the WHYs of one generation which are often the points of departure for the next, to whom the earlier WHYs can appear subjective, conditioned by "unscientific" thinking, even wrong. The glory of science is that this notwithstanding, we often arrive at correct predictions—at least to the extent of the experimental accuracies achievable and often better. I wish to speak about this continuing, ever-sharpening process about the WHYs of physics in the context of the fundamental unification of physical forces on which our generation is engaged.

I can summarize my remarks in terms of three propositions:

(1) The physics of the last century ascribed its deeper WHYs to an all-pervading mechanical aether. Einstein killed this aether, but he substituted for it, something terribly close in spirit—a *dynamical* space-time manifold. Following Einstein, the deepest WHYs of today's physics are to be found as manifestations of what we choose to assume as the basic attributes of the space-time manifold.

(2) So far as dynamics is concerned, our final court of appeal, if all else fails, is the Bootstrap mechanism, the principle of self-consistency of the Universe. This principle may be traced back to the teleological dictum of Leibnitz—so savagely satirised by Voltaire in *Candide*—"The Universe is as it is for what else could it be.".

(3) And finally, there are the Laws of Impotence—so named by Max Born—which all WHYs must respect. These laws of impotence—the glory of the physics of the 20th century—consist of not-to-be-questioned admonitions like: thou shalt not conceive of velocities greater than that of light, to transmit signals; thou shalt quantize angular momentum in units of the Planck's constant (h).

There are other requirements govering the desirable WHYs, like economy of concepts and simplicity (Occam's razor), like eschewing of over-subtlety, like beauty of the mathematics to be used (which somehow appears linked with its unreasonable efficacy). But these are well-known ideas and do not need elaboration.

Sec. 2. To illustrate my remarks, and in particular the questioning by one generation of the WHYs which led the generation before to (relative) truth, consider the classic example of the laws of planetary orbits and celestial gravity theory, associated with the names of Kepler, Newton and Einstein.

Kepler, the first man to give a quantitative description of laws of planetary motion describes thus how he was led to their discovery.

"God reflected on the difference between the curved and the straight and preferred the nobility of the curved.".

"Among bodies, omit....the irregular ones, and only retain those whose faces are equal in side and in angle. There remain five regular bodies of the Greeks: cube, pyramid, dodecahedron, icosahedron and octahedron. ...If the five bodies be fitted into one another and if circles be described both inside and outside all of them, then we obtain precisely the number six of circles....Copernicus has taken just six orbits of this kind, pairs of which are precisely related by the fact that those five bodies fit most perfectly into them.".

Would this type of reasoning be considered "scientific" today?*

* Before we dismiss Kepler's reasoning, reflect on our own generation's partiality for the eight-fold way, or for the *exceptional* Lie groups as candidates for symmetry groups in particle physics, stemming as this partiality usually does from the mathematical "nobility" of these particular constructs!

Kepler described Copernicus as a "blind man feeling his way with a staff". It must have been this act of hubris which in turn had its nemesis in Koestler's description of Kepler as a "sleep-walker".

Kepler was followed by Newton, who washed his hands of the entire search for WHY; "But hitherto I have not been able to discover the cause of...gravity from phenomena and I frame no hypotheses... Hypothesis...has no place in experimental philosophy.".

On this attitude of Newton, Einstein had this to say: "We now realize with special clarity, how much in error are those theorists who believe that theory comes inductively from experiment. Even the great Newton could not free himself from this error (Hypotheses non fingo).".

But had Newton built no hypothesis into his gravity theory? According to Einstein, he had. This was the hypothesis that the gravitational charge (m) which occurs in Newton's Force Law ($F = \frac{m_1 m_2}{r^2}$) *exactly* equals inertial mass—the quantity of matter contained in the bodies which mutually attract. This is the so-called Equivalence Principle.

Sec. 3. To see the force of Einstein's remark about Newton's assumption of the equality of gravitational charge with inertial mass, consider a hydrogen atom which consists of a proton and an electron. In making up the atom, the electron and the proton attract each other both electrically as well as gravitationally. The inertial mass of the atom equals proton's mass *plus* electron's mass *minus* the electrical, as well as the gravitational, binding energies. The ratio of the summed masses of the proton and the electron to the two varieties of binding energies is of the order of $1 : 10^{-8} : 10^{-47}$. Now, Eotvos (in the nineteenth century) in his celebrated torsion experiment, had in fact demonstrated that gravitational charge does equal inertial mass to the extent that, for the hydrogen atom for example, the electrical binding energy ($10^{-8} : 1$) contributes equally to both. But what about the gravitational binding energy? Does the tiny relative number (10^{-47})—ascribable to gravitational binding—also affect inertial mass and gravitational charge equally? What would Newton say?

Einstein's own answer was unambiguous. His WHY for the existence of the gravitational force ascribes this force to space-time dynamics, to the curvature of the four dimensional space-time. His theory incorporates a "strong equivalence" of gravitational charge with inertial mass. But there were rival theories—like those of Brans-Dicke's extension of Einstein's—which denied this equivalence so far as the gravitational binding-energy is concerned. According to these theories, a part of this relative 10^{-47} would not show up in the gravitational charge.

The issue between Einstein and Brans-Dicke was joined, in March 1976, in two beautiful experiments, independently carried out by two teams; one led by Shapiro, the other by Dicke himself. These epic experiments consisted of measuring the mean (Kepler) positions of the earth and the moon to ± 30 cms. through lunar laser ranging measurements. For heavenly test bodies as massive as these, the relative ratio of the gravitational binding energy to the total mass is in excess of $10^{-12}:1$ (and not the miserable, unmeasurable ratio $10^{-47}:1$ obtaining for the hydrogen atom).

To nobody's surprise—except perhaps to Dicke's—Einstein's strong equivalence principle proved to be correct. Dicke's own theory must be discarded, at least to all reasonable values of a new, adjustable parameter in his theory.*

To summarize, Kepler, Newton and Einstein each started with a different WHY for broadly the same set of phenomena. (To be more precise, Newton disclaimed any attempt at formulating a WHY for gravity theory—even though he apparently did build into it an equivalence hypothesis, justified later by Einstein's totally different approach.) Each theory gave predictions commensurate and better than the accuracies of the experiments *then* possible. However, at present, Einstein's approach remains the deepest—and the most accurately predictive—that we know of for explaining the existence—the raison behind—one of Nature's fundamental forces (gravity). Will this for ever be the case? Will this theory need

*Notice, like old soldiers, theories never die; they simply fade away. Thus, one could still save Brans-Dicke's theory, but only by assuming an outrageous value for this adjustable parameter. Other phenomena would then be affected but they are (hitherto) untestable.

modifications, extensions, become part of bigger whole; will it even have to be discarded altogether, together with all its axiomatic sub-structure?

Einstein believed that the discovery of the deep WHY, underlying the other forces of nature will also follow the pattern of "geometrisation" of gravity that he had given to physics. Before I consider this, let me take one more example of differing styles of the offered WHYs at different epochs of physics. The example is from one of the other fundamental forces of Nature—electromagnetism. Maxwell, you may recall, predicted the existence of the electromagnetic radiation on the basis of the "displacement current" which he invented. This is one of the greatest feats of inventive discovery man has ever made—a discovery with few parallels in the change it brought about in the world we live in. Today an A-level student would demonstrate for you the necessity of a "displacement current" from the conservation law of electric charge. But Maxwell, himself, went through a tortuous—and what today might be considered an untenable deduction based on a mechanical model of the aether. In Einstein's phrase, "(This) great change (was) brought about by Faraday, Maxwell and Hertz—as a matter of fact, half-consciously, and against their will—(because) all three of them, throughout their lives considered themselves adherents of the mechanical theory (of the aether).". Notwithstanding this, does anyone here tonight dare feel superior to Maxwell? Even after what I just quoted from Einstein, listen to his reverence for Maxwell: "Imagine Maxwell's feelings when the differential equations he had formulated proved to him that the electromagnetic fields spread in the form of polarized waves and with the speed of light. To few men in the world has such an experience been vouchsafed.".

Sec. 4. Consider now the forces of electromagnetism, and the two nuclear forces, weak and strong, responsible for radioactivity phenomena and for fission and fusion respectively. Recently, theory suggested and experiment confirmed that the weak nuclear force combines with electromagnetism—just as magnetism combined with electricity in the hands of Faraday and Maxwell a century ago—into one single, all embracing

ELECTROWEAK force. The secret of this unification* lay in the extension of the so-called gauge ideas (well-known in electromagnetism) to the weak nuclear force. The characteristic of a gauge force is that such forces are proportional to the "charges" carried by the particles (e.g. $F = \frac{e_1 e_2}{r^2}$ for electromagnetism, $F = \frac{m_1 m_2}{r^2}$ for gravity).

What has been shown is that analogous to the electric charge, there exist three weak charges which determine the strength of the weak nuclear force and that these three charges—together with the electric—form four components of a "single" entity, each component transformable one into the other, through the operations of the group structure SU(2) ×U(1) acting on an "internal symmetry space". I shall attempt to explain what I mean, more humanly, in a moment. But to complete the story: The future theoretical expectation is that the strong nuclear force is also a gauge force and the corresponding strong nuclear charges will eventually unite with the electroweak charges to make up a single entity, belonging to a still "internal symmetry group", of which the electroweak SU(2) ×U(1) is a part.† From the concept of the electroweak

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*A crucial role in the demonstration of this electroweak unification was played by the ideas of "spontaneous" symmetry breaking. To motivate these, one has to invoke self-consistency (my second proposition, *see* Sec. 1) and to build in a special type of symmetrical potential into the structure of the theory—a potential which (surprisingly enough) yields solutions with less symmetry than what we started from. This potential should guarantee that the weak nuclear force remains short-range as observed, without affecting the long-range character of the electromagnetic force. There is a welcome price which one pays for inventing such a potential; one predicts the existence of a hitherto undetected particle—the so called Higgs particle—which is currently being searched for. This particle is welcome, for its existence would show that we are on the right track.

It is this sort of quantitative prediction, which distinguishes our use and our version of the self-consistency principle in physics, from empty philosophising.

†Experiments to demonstrate this have just gone underway with Brookhaven-Irvine-Wisconsin and Milan-Turin-CERN-University College-Oxford collaborations. These are experiments designed to demonstrate that the proton is unstable with a half-life of the order of 10^{30} years. Hitherto the proton has been believed to be stable. (Compare 10^{30} years with the unmentionably tiny life of the Universe (of the order of 10^{10} years).

force we shall, we hope, progress soon to the concept of a unified ELECTRO-NUCLEAR force, comprising electromagnetism as well as the two types of the nuclear force.

I have used the word "internal symmetry space" to designate that mysterious something which provides the present WHY for these unified gauge theories. Charge—electric, weak-nuclear, strong-nuclear—is a manifestation of the existence of an "internal" symmetry structure and of the postulated symmetries of laws of physics for rotations and other transformation in this mysterious internal space. The analogy of the internal space is with the familiar space-time. And the analogy of the electric and nuclear charges is with the gravitational charge—the inertial mass—which is associated with the translation-symmetry of the four-dimensional space-time* continuum.

The question which arose in the nineteen-thirties when "internal symmetry spaces" were first invented by Heisenberg and Kemmer and which has become more and more insistent with the success of gauge ideas is this: Are these "internal spaces" purely mathematical constructs, or do they represent realistic adjunct to the four dimensional space-time we are familiar with.

To take one example, one of the attempts currently being made is to describe physics in an 11-dimensional space-time. Of the 11-dimensions, four are the familiar space-time dimensions whose curvature is related to gravity and the other seven dimensions correspond to an internal symmetry space. In the theory advanced, the seven dimensions curled in upon themselves 10^{-43} secs. after the Big Bang, attaining a size of the order of 10^{-33} cms. and no more. We live on a cylinder in 11-dimensional space, our major source of sensory apprehension of these extra dimensions being the existence of charges—electric, weak-nuclear and strong-nuclear and the corresponding forces as manifestations of their curvature. Thus will Einstein's final dream (with which he lived for thirty-five years

*Translation-symmetry is the statement that the laws of physics are independent of the location of where an experiment to test them is performed. This is one example of symmetry which we choose to ascribe to space-time structure; *cf.* the first proposition of Sec. 1. The experimental consequence of this assumed symmetry is the empirically testable conservation of energy and momentum.

of uniting gravity) with the other (electronuclear) forces be eventually realized?

Exciting idea, which may or may not work quantitatively! But one question already arises; why the difference between the four familiar space-time dimensions and the seven internal ones? Why may the one lot curl in upon themselves, while the other does not? For the present, we shall make this plausible through the self-consistency principle; we shall invent a potential which will guarantee this as the only stable self-consistent dynamical system which can exist. There will be subtle physical consequences of this perhaps, in the form of remnants, like the black body radiation which was a remnant of the Big Bang. We shall search for these. Even if we find them, the next generation may perhaps question this entire mode of thought—particularly if a small discrepancy with our predictions is detected—and the cycle of questioning and answering might start all over again. Even today, an obvious question would be: Why eleven dimensions; why not a wholesome number, like thirteen? Or is this once again, due to the operation of the Bootstrap, the self-consistency principle?

There is an alternative suggestion to these extra dimensions which seeks to explain charges (other than gravitational) within the context of no more than a conventional four dimensional space-time. This suggestion, due to Wheeler, Schemberg and Hawking, does not add in new dimensions; it instead associates the electric and the nuclear charges to space-time topology—space-time Cruyere-cheesiness, worm-holes of the granular size of the order of 10^{-33} cms. The idea is attractive. Topology, you may recall, is concerned with "global" aspects as contrasted with the "differential" aspects of the present tradition in physics. It thus represents a real break with the past. Unfortunately—and I say this deliberately and ungratefully, in order to provoke some of my friends, in this audience—my own feeling is that the mathematics of topology, in respect of what we need, has not progressed beyond the Mobius strip and the Klein-bottle. Topology—as a language for physics is not yet capable of supporting the edifice the physicist may wish to erect on it. Could it be that our generation is defeated by the lack of development of a necessary

mathematical discipline in a direction that we need? This has never happened before in the history of physics, but on this note, I would like to leave you to ponder on the deeper WHYs, appropriate to the physics of today—and tomorrow.

11. Salam's Paper on "Gauge Unification of Fundamental Forces" (Technical Paper).

In June 1938, Sir George Thomson, then Professor of Physics at Imperial College, London, delivered his 1937 Nobel Lecture. Speaking of Alfred Nobel, he said: "The idealism which permeated his character led him to...(being) as much concerned with helping science as a whole, as individual scientists....The Swedish people under the leadership of the Royal Family and through the medium of the Royal Academy of Sciences have made Nobel Prizes one of the chief causes of the growth of the prestige of science in the eyes of the world....As a recipient of Nobel's generosity, I owe sincerest thanks to them as well as to him."

I am sure I am echoing my colleagues' feelings as well as my own, in reinforcing what Sir George Thomson said—in respect of Nobel's generosity and its influence on the growth of the prestige of science. Nowhere is this more true than in the developing world. And it is in this context that I have been encouraged by the Permanent Secretary of the Academy—Professor Carl Gustaf Bernhard—to say a few words before I turn to the scientific part of my lecture.

Scientific thought and its creation is the common and shared heritage of mankind. In this respect, the history of science, like the history of all civilization, has gone through cycles. Perhaps I can illustrate this with an actual example.

Seven hundred and sixty years ago, a young Scotsman left his native glens to travel south to Toledo in Spain. His name was Michael, his goal to live and work at the Arab Universities of Toledo and Cordova, where the greatest of Jewish scholars, Moses bin Maimoun, had taught a generation before.

Michael reached Toledo in 1217 AD. Once in Toledo, Michael formed the ambitious project of introducing Aristotle to Latin Europe, translating not from the original Greek, which he knew not, but from the Arabic translation then taught in Spain. From Toledo, Michael travelled to Sicily, to the Court of Emperor Frederick II.

Visiting the medical school at Salerno, chartered by Frederick in 1231, Michael met the Danish physician, Henrick Harpestraeng—later to become Court Physician of Eric IV

Waldemarsson. Henrick had come to Salerno to compose his treatise on blood-letting and surgery. Henrik's sources were the medical canons of the great clinicians of Islam, Al-Razi and Avicenna, which only Michael the Scot could translate for him.

Toledo's and Salerno's schools, representing as they did the finest synthesis of Arabic, Greek, Latin and Hebrew scholarship, were some of the most memorable of international assays in scientific collaboration. To Toledo and Salerno came scholars not only from the rich countries of the East, like Syria, Egypt, Iran and Afghanistan, but also from developing lands of the West like Scotland and Scandinavia. Then, as now, there were obstacles to this international scientific concourse, with an economic and intellectual disparity between different parts of the world. Men like Michael the Scot or Henrik Harpestraeng were singularities. They did not represent any flourishing schools of research in their own countries. With all the best will in the world their teachers at Toledo and Salerno doubted the wisdom and value of training them for advanced scientific research. At least one of his masters counselled young Michael the Scot to go back to clipping sheep and the weaving of woollen cloths.

In respect of this cycle of scientific disparity, perhaps I can be more quantitative. George Sarton, in his monumental five-volume *History of Science* chose to divide his story of achievement in sciences into ages, each age lasting half a century. With each half century he associated one central figure. Thus 450 BC—400 BC Sarton calls the Age of Plato; this is followed by half centuries of Aristotle, of Euclid, of Archimedes and so on. From 600 AD to 650 AD is the Chinese half century of Hsiian Tsang, from 650 to 700 AD that of I-Ching, and then from 750 AD to 1100 AD—350 years continuously—it is the unbroken succession of the Ages of Jabir, Khwarizmi, Razi, Masudi, Wafa, Biruni and Avicenna, and then Omar Khayam—Arabs, Turks, Afghans and Persians—men belonging to the culture of Islam. After 1100 appear the first Western names; Gerard of Cremona, Roger Bacon—but the honours are still shared with the names of Ibn-Rushd (Averroes), Moses Bin Maimoun, Tusi and Ibn-Nafis—the man who anticipated Harvey's theory of circulation of blood. No Sarton has yet

chronicled the history of scientific creativity among the pre-Spanish Mayas and Aztecs, with their invention of the zero, of the calendars of the moon and Venus and of their diverse pharmacological discoveries, including quinine, but the outline of the story is the same—one of undoubted superiority to the Western contemporary correlates.

After 1350, however, the developing world loses out except for the occasional flash of scientific work, like that of Ulugh Beg—the grandson of Timurlane, in Samarkand in 1400 AD; or of Maharaja Jai Singh of Jaipur in 1720—who corrected the serious errors of the then Western tables of eclipses of the sun and the moon by as much as six minutes of arc. As it was, Jai Singh's techniques were surpassed soon after with the development of the telescope in Europe. As a contemporary Indian chronicler wrote: "With him on the funeral pyre, expired also all science in the East." And this brings us to this century when the cycle begun by Michael the Scot turns full circle, and it is we in the developing world who turn to the Westwards for science. As Al-Kindi wrote 1100 years ago: "It is fitting then for us not to be ashamed to acknowledge truth and to assimilate it from whatever source it comes to us. For him who scales the truth there is nothing of higher value than truth itself; it never cheapens nor abases him."

Ladies and Gentlemen,

It is in the spirit of Al-Kindi that I start my lecture with a sincere expression of gratitude to the modern equivalents of the Universities of Toledo and Cordova, which I have been privileged to be associated with—Cambridge, Imperial College and the Centre at Trieste.

I. Fundamental Particles, Fundamental Forces and Gauge Unification.

The Nobel lectures this year are concerned with a set of ideas relevant to the gauge unification of the electromagnetic force with the weak nuclear force. These lectures coincide nearly with the 100th death-anniversary of Maxwell, with whom the first unification of forces (electric with the magnetic)

matured and with whom gauge theories orginated. They also nearly coincide with the 100th anniversary of the birth of Einstein—the man who gave us the vision of an ultimate unification of all forces.

The ideas of today started more than twenty years ago, as gleams in several theoretical eyes. They were brought to predictive maturity over a decade back. And they started to receive experimental confirmation some six years ago.

In some senses then, our story has a fairly long background in the past. In this lecture I wish to examine some of the theoretical gleams of today and ask the question if these may be the ideas to watch for maturity twenty years from now.

From time immemorial, man has desired to comprehend the complexity of nature in terms of as few elementary concepts as possible. Among his quests—in Feynman's words—has been the one for "wheels within wheels"—the task of natural philosophy being to discover the innermost wheels if any such exist. A second quest has concerned itself with the fundamental forces which make the wheels go round and enmesh with one another. The greatness of gauge ideas—of gauge field theories—is that they reduce these two quests to just one; elementary particles (described by relativistic quantum fields) are representations of certain charge operators, corresponding to gravitational mass, spin, flavour, colour, electric charge and the like, while the fundamental forces are the forces of attraction or repulsion between these same *charges*. A third quest seeks for a *unification* between the charges (and thus of the forces) by searching for a single entity, of which the various charges are components in the sense that they can be transformed one into the other.

But are all fundamental forces gauge forces? Can they be understood as such, in terms of charges—and their corresponding currents—only? And if they are, how many charges? What unified entity are the charges components of? What is the nature of charge? Just as Einstein comprehended the nature of gravitational charge in terms of space-time curvature, can we comprehend the nature of the other charges—the nature of the entire unified set, *as a set*, in terms of something equally profound? This briefly is the dream, much reinforced by the verification of gauge theory predictions. But before I

examine the new theoretical ideas on offer for the future in this particular context, I would like your indulgence to range over a one-man, purely subjective, perspective in respect of the developments of the last twenty years themselves. The point I wish to emphasise during this part of my talk was well made by G.P. Thomson in his 1937 Nobel Lecture. G.P. said "....The goddess of learning is fabled to have sprung full grown from the brain of Zeus, but it is seldom that a scientific conception is born in its final form, or owns a single parent. More often it is the product of a series of minds, each in turn modifying the ideas of those that came before, and providing material for those that come after."

II. The Emergence of Spontaneously Broken SU(2)×U(1) Gauge Theory.

I started physics research thirty years ago as an experimental physicist in the Cavendish, experimenting with tritium-deuterium scattering. Soon I knew the craft of experimental physics was beyond me—it was the sublime quality of patience—patience in accumulating data, patience with recalcitrant equipment—which I sadly lacked. Reluctantly I turned my papers in, and started instead on quantum field theory with Nicholas Kemmer in the exciting department of P.A.M. Dirac.

The year 1949 was the culminating year of the Tomonaga-Schwinger-Feynman-Dyson reformulation of renormalized Maxwell-Dirac gauge theory, and its triumphant experimental vindication. A field theory must be renormalizable and be capable of being made free of infinities—first discussed by Waller—if perturbative calculations with it are to make any sense. More—a renormalizable theory, with no dimensional parameter in its interaction term, connotes *somehow* that the fields represent "structureless" elementary entities. With Paul Matthews, we started on an exploration of renormalizability of meson theories. Finding that renormalizability held only for spin-zero mesons and that these were the only mesons that empirically existed then, (pseudoscalar pions, invented by Kemmer, following Yukawa) one felt thrillingly euphoric that with the triplet of pions (considered as the carriers of the strong nuclear force between the proton-neutron doublet)

one might resolve the dilemma of the origin of this particular force which is responsible for fusion and fission. By the same token, the so-called weak nuclear force—the force responsible for β-radioactivity (and described then by Fermi's non-renormalizable theory) had to be mediated by some unknown spin-zero mesons if it was to be renormalizable. If massive charged spin-one mesons were to mediate this interaction, the theory would be non-renormalizable, according to the ideas then.

Now this agreeably renormalizable spin-zero theory for the pion was a field theory, but not a gauge field theory. There was no conserved charge which determined the pionic interaction. As is well known, shortly after the theory was elaborated, it was found wanting. The $(\frac{3}{2},\frac{3}{2})$ resonance Δ effectively killed it off as a fundamental theory; we were dealing with a complex dynamical system, not "structureless" in the field-theoretic sense.

For me, personally, the trek to gauge theories as candidates for fundamental physical theories started in earnest in September 1956—the year I heard at the Seattle Conference Professor Yang expound his and Professor Lee's ideas[1] on the possibility of the hitherto sacred principle of left-right symmetry, being violated in the realm of the *weak nuclear force*. Lee and Yang had been led to consider abandoning left-right symmetry for weak nuclear interactions as a possible resolution of the (τ,θ) puzzle. I remember travelling back to London on an American Air Force (MATS) transport flight. Although I had been granted, for that night, the status of a Brigadier or a Field Marshal—I don't quite remember which—the plane was very uncomfortable, full of crying servicemen's children—that is, the children were crying, not the servicemen. I could not sleep. I kept reflecting on why Nature should violate left-right symmetry in weak interactions. Now the hallmark of most weak interactions was the involvement in radioactivity phenomena of Pauli's neutrino. While crossing over the Atlantic, came back to me a deeply perceptive question about the neutrino which Professor Rudolf Peierls had asked when he was examining me for a Ph.D. a few years before. Peierls' question was: "The photon mass is zero because of Maxwell's

principle of a gauge symmetry for electromagnetism; tell me, why is the neutrino mass zero?" I had then felt somewhat uncomfortable at Peierls, asking for a Ph.D. viva, a question of which he himself said he did not know the answer. But during that comfortless night the answer came. The analogue for the neutrino of the gauge symmetry for the photon existed; it had to do with the masslessness of the neutrino, with symmetry under the γ_5 transformation[2] (later christened "chiral symmetry"). The existence of this symmetry for the massless neutrino must imply a combination $(1+\gamma_5)$ or $(1-\gamma_5)$ for the neutrino interactions. Nature had the choice of an aesthetically satisfying but a left-right symmetry violating theory, with a neutrino which travels exactly with the velocity of light; or alternatively a theory where left-right symmetry is preserved, but the neutrino has a tiny mass—some ten thousand times smaller than the mass of the electron.

It appeared at that time clear to me what choice Nature must have made. Surely, left-right symmetry must be sacrificed in all neutrino interactions. I got off the plane the next morning, naturally very elated. I rushed to the Cavendish, worked out the Michel parameter and a few other consequences of γ_5 symmetry, rushed out again, got onto a train to Birmingham where Peierls lived. To Peierls I presented my idea; he had asked the original question; could he approve of the answer? Peierls' reply was kind but firm. He said: "I do not believe left-right symmetry is violated in weak nuclear forces at all. I would not touch such ideas with a pair of tongs." Thus rebuffed in Birmingham, like Zuleika Dobson, I wondered where I could go next and the obvious place was CERN in Geneva, with Pauli—the father of the neutrino—nearby in Zurich. At that time CERN lived in a wooden hut just outside Geneva airport. Besides my friends, Prentki and d'Espagnat, the hut contained a gas ring on which was cooked the staple diet of CERN—Entrecote a la creme. The hut also contained Professor Villars of MIT, who was visiting Pauli the same day in Zurich. I gave him my paper. He returned the next day with a message from the Oracle: "Give my regards to my friend Salam and tell him to think of something better". This was discouraging, but I was compensated by Pauli's excessive kindness a few months later, when Mrs. Wu's,[3] Lederman's[4] and Telegdi's[5] experi-

ments were announced showing that left-right symmetry was indeed violated and ideas similar to mine about chiral symmetry were expressed independently by Landau[6] and Lee and Yang.[7] I received Pauli's first somewhat apologetic letter on 24 January 1957. Thinking that Pauli's spirit should by now be suitably crushed, I sent him two short notes[8] I had written in the meantime. These contained suggestions to extend chiral symmetry to electrons and muons, assuming that their masses were a consequence of what has come to be known as dynamically spontaneous symmetry breaking. With chiral symmetry for electrons, muons and neutrinos, the only mesons that could mediate weak decays of the muons would have to carry spin one. Reviving thus the notion of charged intermediate *spin-one* bosons, one could then postulate for these a type of gauge invariance which I called the "neutrino gauge". Pauli's reaction was swift and terrible. He wrote on 30th January 1957, then on 18 February and later on 11, 12 and 13 March: "I am reading (along the shores of Lake Zurich) in bright sunshine quietly your paper...." "I am very much startled on the title of your paper 'Universal Fermi interaction'....For quite a while I have for myself the rule if a theoretician says *universal* it just means pure nonsense. This holds particularly in connection with the Fermi interaction, but otherwise too, and now you too, Brutus, my son, come with this word...." Earlier, on 30 January, he had written: "There is a similarity between this type of gauge invariance and that which was published by Yang and Mills.... In the latter, of course, no γ_5 was used in the exponent" and he gave me the full reference of Yang and Mills' paper; [Phys. Rev. *96*, 191 (1954).] I quote from his letter: "However, there are dark points in your paper regarding the vector field B_μ. If the rest mass is infinite (or very large), how can this be compatible with the gauge transformation $B_\mu \to B_\mu - \partial_\mu \Lambda$?" and he concludes his letter with the remark: "Every reader will realize that you deliberately conceal here something and will ask you the same questions". Although he signed himself "With friendly regards", Pauli had forgotten his earlier penitence. He was clearly and rightly on the warpath.

Now the fact that I was using gauge ideas similar to the Yang-Mills [non-Abelian SU(2)-invariant] gauge theory was

no news to me. This was because the Yang-Mills theory[9] [which married gauge ideas of Maxwell with the internal symmetry SU(2) of which the proton-neutron system constituted a doublet] had been independently invented by a Ph.D. pupil of mine, Ronald Shaw,[10] at Cambridge at the same time as Yang and Mills had written. Shaw's work is relatively unknown; it remains buried in his Cambridge thesis. I must admit I was taken aback by Pauli's fierce prejudice against universalism—against what we would today call unification of basic forces—but I did not take this too seriously. I felt this was a legacy of the exasperation which Pauli had always felt at Einstein's somewhat formalistic attempts at unifying gravity with electromagnetism—forces which in Pauli's phrase "cannot be joined —for God hath rent them asunder". But Pauli was absolutely right in accusing me of darkness about the problem of the masses of the Yang-Mills fields; one could not obtain a mass without wantonly destroying the gauge symmetry one had started with. And this was particularly serious in this context, because Yang and Mills had conjectured the desirable renormalizability of their theory with a proof which relied heavily and exceptionally on the masslessness of their spin-one intermediate mesons. The problem was to be solved only seven years later with the understanding of what is now known as Higgs mechanism, but I will come back to this later.

Be that as it may, the point I wish to make from this exchange with Pauli is that already in early 1957, just after the first set of parity experiments, many ideas coming to fruition now, had started to become clear. These are:

1. First was the idea of chiral symmetry leading to a $V-A$ theory. In those early days my humble suggestion[2,8] of this was limited to neutrinos, electrons and muons only, while shortly after, that year, Sudarshan and Marshak[11], Gell-Mann and Feynman,[12] and Sakurai[13] had the courage to postulate γ_5 symmetry for baryons as well as leptons, making this into a universal principle of physics.*

*Today we believe protons and neutrons are composites of quarks, so that γ_5 symmetry is now postulated for the elementary entities of today—the quarks.

Concomitant with the $(V - A)$ theory was the result that if weak interactions are mediated by intermediate mesons, these mesons must carry spin one.

2. Second, was the idea of spontaneous breaking of chiral symmetry to generate electron and muon masses: though the price which those latter-day Shylocks, Nambu and Jona-Lasinio[14] and Goldstone[15] exacted for this (i.e. the appearance of massless scalars), was not yet appreciated.

3. And finally, though the use of a Yang-Mills-Shaw (non-Abelian) gauge theory for describing spin-one intermediate charged mesons was suggested already in 1957, the giving of masses to the intermediate bosons through spontaneous symmetry breaking, in a manner to preserve the renormalizability of the theory, was to be accomplished only during a long period of theoretical development between 1963 and 1971.

Once the Yang-Mills-Shaw ideas were accepted as relevant to the charged weak currents—to which the charged intermediate mesons were coupled in this theory—during 1957 and 1958 was raised the question of what was the third component of the SU(2) triplet, of which the charged weak currents were the two members. There were the two alternatives: the electroweak unification suggestion, where the electromagnetic current was assumed to be this third component; and the rival suggestion that the third component was a neutral current unconnected with electroweak unification. With hindsight, I shall call these the Klein[16] (1938) and the Kemmer[17] (1937) alternatives. The Klein suggestion, made in the context of a Kaluza-Klein five-dimensional space-time, is a real tour-de-force; it combined two hypothetical spin-one charged mesons with the photon in one multiplet, deducing from the compactification of the fifth dimension, a theory which looks like Yang-Mills-Shaw's. Klein intended his charged mesons for *strong* interactions, but if we read charged *weak* mesons for Klein's *strong* ones, one obtains the theory independently suggested by Schwinger[18] (1957), though Schwinger, unlike Klein, did not build in any non-Abelian gauge aspects. With just these non-Abelian Yang-Mills gauge aspects very much to the fore, the idea of uniting weak interactions with electromagnetism

was developed by Glashow[19] and Ward and myself[20] in late 1958. The rival Kemmer suggestion of a global SU(2)-invariant triplet of weak charged and neutral currents was independently suggested by Bludman[21] (1958) in a gauge context and this is how matters stood till 1960.

To give you the flavour of, for example, the year 1960, there is a paper written that year by Ward and myself[22] with the statement: "Our basic postulate is that it should be possible to generate strong, weak and electromagnetic interaction terms with all their correct symmetry properties (as well as with clues regarding their relative strengths) by making local gauge transformations on the kinetic energy terms in the free Lagrangian for all particles. This is the statement of an ideal which, in this paper at least, is only very partially realized". I am not laying a claim that we were the only ones who were saying this, but I just wish to convey to you the temper of the physics of twenty years ago—qualitatively no different today from then. But what a quantitative difference the next twenty years made, first with new and far-reaching developments in theory—and then, thanks to CERN, Fermilab, Brookhaven, Argonne, Serpukhov and SLAC in testing it!

So far as theory itself is concerned, it was the next seven years between 1961-67 which were the crucial years of quantitative comprehension of the phenomenon of spontaneous symmetry breaking and the emergence of the SU(2) $\times$ U(1) theory in a form capable of being tested. The story is well known and Steve Weinberg has already spoken about it. So I will give the barest outline. First there was the realization that the two alternatives mentioned above a pure electromagnetic current *versus* a pure neutral current—Klein-Schwinger *versus* Kemmer-Bludman—were not alternatives; they were complementary. As was noted by Glashow[23] and independently later by Ward and myself[24], both types of currents and the corresponding gauge particles ($W^{\pm}$, Z^0 and Υ) were needed in order to build a theory that could simultaneously accommodate parity violation for weak and parity conservation for the electromagnetic phenomena. Second, there was the influential paper of Goldstone[25] in 1961 which, utilizing a non-gauge self-interaction between scalar particles, showed that the price of spontaneous breaking of a continuous internal symmetry was

the appearance of zero mass scalars—a result foreshadowed earlier by Nambu. In giving a proof of this theorem[26] with Goldstone I collaborated with Steve Weinberg, who spent a year at Imperial College in London.

I would like to pay here a most sincerely felt tribute to him and to Sheldon Glashow for their warm and personal friendship.

I shall not dwell on the now well-known contributions of Anderson,[27] Higgs,[28] Brout & Englert,[29] Guralnik, Hagen and Kibble[30] starting from 1963, which showed the way how spontaneous symmetry breaking using spin-zero fields could generate vector-meson masses, defeating Goldstone at the same time. This is the so-called Higgs mechanism.

The final steps towards the electroweak theory were taken by Weinberg[31] and independently by myself[32] (with Kibble at Imperial College tutoring me about the Higgs phenomena). We were able to complete the present formulation of the spontaneously broken SU(2)×U(1) theory so far as leptonic weak interactions were concerned—with one parameter $\sin^2 Q$ describing all weak and electromagnetic phenomena and with one isodoublet Higgs multiplet. An account of this development was given during the contribution[32] to the Nobel Symposium (organized by Nils Svartholm and chaired by Lamek Hulthen held at Gothenburg after some postponements, in early 1968). As is well known, we did not then, and still do not, have a prediction for the scalar Higgs mass.

Both Weinberg and I suspected that this theory was likely to be renormalizable.* Regarding spontaneously broken Yang-Mills-Shaw theories in general this had earlier been suggested by Englert, Brout and Thiry.[29] But this subject

*When I was discussing the final version of the SU(2)×U(1) theory and its possible renormalizability in Autumn 1967 during a post-doctoral course of lectures at Imperial College, Nino Zichichi from CERN happened to be present. I was delighted because Zichichi had been badgering me since 1958 with persistent questioning of what theoretical avail his precise measurements on (g-2) for the muon as well as those of the muon lifetime were, when not only the magnitude of the electromagnetic corrections to weak decays was uncertain, but also conversely the effect of non-renormalizable weak interactions on "renormalized" electromagnetism was so unclear.

was not pursued seriously except in Veltman's school at Utrecht, where the actual proof of renormalizability was given by 't Hooft[33] in 1971. This was elaborated further by that remarkable physicist the late Benjamin Lee,[34] working with Zinn Justin, and by 't Hooft and Veltman.[35] This followed on the earlier basic advances in Yang-Mills calculational technology by Feynman,[36] Dewitt,[37] Faddeev and Popov,[38] Mandelstam,[39] Fradkin and Tyutin,[40] Boulware,[41] Taylor,[42] Slavnov,[43] Strathdee[44] and Salam. In Coleman's eloquent phrase: "'t Hooft's work turned the Weinberg-Salam frog into an enchanted prince". Just before had come the GIM (Glashow, Illiopoulos and Maiani) mechanism,[45] emphasising that the existence of the fourth charmed quark (postulated earlier by several authors) was essential to the natural resolution of the dilemma posed by the absence of strangeness-violating currents. This tied in naturally with the understanding of the Steinberger-Schwinger-Rosenberg-Bell-Jackiw-Adler anomaly[46] and its removal for SU(2)×U(1) by the parallelism of four quarks and four leptons, pointed out by Bouchiat, Illiopoulos and Meyer and independently by Gross and Jackiw.[47]

If one has kept a count, I have so far mentioned around fifty theoreticians. As a failed experimenter, I have always felt envious of the ambience of large experimental teams and it gives me the greatest pleasure to acknowledge the direct or the indirect contributions of the "series of minds" to the spontaneously broken SU(2)×U(1) gauge theory. My profoundest personal appreciation goes to my collaborators at Imperial College, Cambridge and the Trieste Centre, John Ward, Paul Matthews, Jogesh Pati, John Strathdee, Tom Kibble and to Nicholas Kemmer.

In retrospect, what strikes me most about the early part of this story is how uninformed all of us were, not only of each other's work, but also of work done earlier. For example, only in 1972 did I learn of Kemmer's paper written at Imperial College in 1937.

Kemmer's argument essentially was that Fermi's weak theory was not globally SU(2)-invariant and should be made so—though not for its own sake but as a prototype for strong interactions. Then this year I learnt that earlier, in 1936, Kemmer's Ph.D. supervisor, Gregor Wentzel,[48] had intro-

duced (the yet undiscovered) analogues of lepto-quarks, whose mediation could give rise to neutral currents after a Fierz reshuffle. And only this Summer, Cecilia Jarlskog at Bergen rescued Oscar Klein's paper from the anonymity of the Proceedings of the International Institute of Intellectual Cooperation of Paris, and we learnt of his anticipation of a theory similar to Yang-Mills-Shaw's long before these authors. As I indicated before, the interesting point is that Klein was using his triplet, of two charged mesons plus the photon, not to describe weak interaction but for strong nuclear force unification with the electromagnetic—something our generation started on only in 1972—and not yet experimentally verified. Even in this recitation I am sure I have inadvertantly left off some names of those who have in some way contributed to SU(2) $\times$ U(1). Perhaps the moral is that not unless there is the prospect of quantitative verification, does a qualitative idea make its impress in physics.

And this brings me to experiment, and the year of the Gargamelle.[49] I still remember Paul Matthews and I getting off the train at Aix-en-Provence for the 1973 European Conference and foolishly deciding to walk with our rather heavy luggage to the student hostel where we were billeted. A car drove from behind us, stopped, and the driver leaned out. This was Musset whom I did not know well personally then. He peeped out of the window and said: "Are you Salam?" I said: "Yes". He said: "Get into the car. I have news for you. We have found neutral currents." I will not say whether I was more relieved for being given a lift because of our heavy luggage or for the discovery of neutral currents. At the Aix-en-Provence meeting that great and modest man, Lagarrigue, was also present and the atmosphere was that of a carnival—at least this is how it appeared to me. Steve Weinberg gave the rapporteur's talk with T.D. Lee as the chairman. T.D. was kind enough to ask me to comment after Weinberg finished. That Summer Jogesh Pati and I had predicted proton decay within the context of what is now called grand unification and in the flush of this excitement I am afraid I ignored weak neutral currents as a subject which had already come to a successful conclusion, and concentrated on speaking of the possible decays of the proton. I understand now that proton decay

experiments are being planned in the United States by the Brookhaven, Irvine and Michigan and the Wisconsin-Harvard groups and also by a European collaboration to be mounted in the Mont Blanc Tunnel Garage No. 17. The later quantitative work on neutral currents at CERN, Fermilab., Brookhaven, Argonne and Serpukhov is, of course, history, but a special tribute is warranted to the beautiful SLAC-Yale-CERN experiment[50] of 1978 which exhibited the effective Z^0-photon interference in accordance with the predictions of the theory. This was foreshadowed by Barkov *et al's* experiments[51] at Novosibirsk in the USSR in their exploration of parity-violation in the atomic potential for bismuth. There is the apocryphal story about Einstein, who was asked what he would have thought if experiment had not confirmed the light deflection predicted by him. Einstein is supposed to have said: "Madam, I would have thought the Lord has missed a most narvellous opportunity". I believe, however, that the following quote from Einstein's Herbert Spencer Lecture of 1933 expresses his, my colleagues' and my own views more accurately. "Pure logical thinking cannot yield us any knowledge of the empirical world; all knowledge of reality starts from experience and ends in it." This is exactly how I feel about the Gargamelle-SLAC experience.

III. The Present and its Problems

Thus far we have reviewed the last twenty years and the emergence of SU(2)$\times$U(1), with the twin developments of a gauge theory of basic interactions, linked with internal symmetries, and of the spontaneous breaking of these symmetries. I shall first summarize the situation as we believe it to exist now and the immediate problems. Then we turn to the future.

1. To the level of energies explored, we believe that the following sets of particles are "structureless" (in a field-theoretic sense) and, at least to the level of energies explored hitherto, constitute the elementary entities of which all other objects are made.

SU (3) triplets

Family I quarks	$\left\{\begin{matrix} u_R, & u_Y, & u_B \\ d_R, & d_Y, & d_B \end{matrix}\right\}$	Leptons	$\begin{bmatrix}\nu_e \\ e\end{bmatrix}$	SU(2) doublets
Family II quarks	$\left\{\begin{matrix} c_R, & c_Y, & c_B \\ s_R, & s_Y, & s_B \end{matrix}\right\}$	Leptons	$\begin{bmatrix}\nu_\mu \\ \mu\end{bmatrix}$	,,
Family III quarks	$\left\{\begin{matrix} t_R, & t_Y, & t_B \\ b_R, & b_Y, & b_B \end{matrix}\right\}$	Leptons	$\begin{bmatrix}\nu_\tau \\ \tau\end{bmatrix}$	,,

Together with their antiparticles each family consists of 15 or 16 two-component fermions (15 or 16 depending on whether the neutrino is massless or not). The third family is still conjectural, since the top quark (^{t}R, ^{t}y, ^{t}B) has not yet been discovered. Does this family really follow the pattern of the other two? Are there more families? Does the fact that the families are replicas of each other imply that Nature has discovered a dynamical stability about a system of 15 (or 16) objects, and that by this token there is a more basic layer of structure underneath?[52]

2. Note that quarks come in three colours: Red (R), Yellow (Y) and Blue (B). Parallel with the electroweak SU(2)×U(1), a gauge field* theory [SUc (3)] of strong (quark) interactions (quantum chromodynamics, QCD)[53] has emerged which gauges the three colours. The indirect discovery of the (eight) gauge bosons associated with QCD (gluons), has already been surmised by the groups at DESY.[54]

3. All known baryons and mesons are singlets of colour SUc(3). This has led to a hypothesis that colour is always confined. One of the major unsolved problems of field theory

* "To my mind the most striking feature of theoretical physics in the last thirty-six years is the fact that not a single new theoretical idea of a fundamental nature has been successful. The notions of relativistic quantum theory.......have in every instance proved stronger than the revolutionary ideas......of a great number of talented physicists. We live in a dilapidated house and we seem to be unable to move out. The difference between this house and a prison is hardly noticeable"—Res Jost (1963) in Praise of Quantum Field Theory (Siena European Conference).

is to determine if QCD—treated non-perturbatively—is capable of confining quarks and gluons.

4. In respect of the electroweak $SU(2) \times U(1)$, all known experiments on weak and electromagnetic phenomena below 100 GeV carried out to date agree with the theory which contains one theoretically undetermined parameter $\sin^2\theta = 0.230 \pm 0.009$.[55] The predicted values of the associated gauge boson ($W^\pm$ and Z^0) masses are: $m_W \approx 77\text{-}84$ GeV, $m_Z \approx 89\text{-}95$ GeV, for $0.25 \geq \sin^2 Q \geq 0.21$ that of the parameter $\left[\varrho = \frac{m_W}{m_Z \cos Q}\right]$?

Currently this has been determined from the ratio of neutral to charged current cross-sections. The predicted value $\varrho = 1$ for weak iso-doublet Higgs is to be compared with the experimental*) $\varrho = 1.00 \pm 0.02$.

6. Why does Nature favour the simplest suggestion in $SU(2) \times U(1)$ theory of the Higgs scalars being iso-doublet?** Is there just one physical Higgs? Of what mass? At present the Higgs interactions with leptons, quarks as well as their self-interactions are non-gauge interactions. For a three-family (6-quark) model, 21 out of the 26 parameters needed, are attributable to the Higgs interactions. Is there a basic principle, as compelling and as economical as the gauge principle, which embraces the Higgs sector? Alternatively, could the Higgs phenomenon itself be a manifestation of a dynamical breakdown of the gauge symmetry.**

*The one-loop radiative corrections to ϱ suggest that the maximum mass of leptons contributing to ϱ is less than 100 GeV.[56]

**To reduce the arbitrariness of the Higgs couplings and to motivate their iso-doublet character, one suggestion is to use supersymmetry. Supersymmetry is a Fermi-Bose symmetry, so that iso-doublet leptons like (ν_e, e) or (ν_μ, μ) in a supersymmetric theory must be accompanied in the same multiplet by iso-doublet Higgs.
Alternatively, one may identify the Higgs as composite fields associated with bound states of a yet new level of elementary particles and new forces (Dimopoulos & Susskind,[57] Weinberg[58] and 't Hooft) of which, at present low energy, we have no cognisance and which may manifest themselves in the 1-100 TeV range. Unfortunately, both these ideas at first sight appear to introduce complexities, though in the context of a wider theory, which spans energy scales upto much higher masses, a satisfactory theory of the Higgs phenomena, incorporating these, may well emerge.

7. Finally there is the problem of the families; is there a distinct SU(2) for the first, another for the second as well as a third SU(2), with spontaneous symmetry breaking such that the SU(2) apprehended by present experiment is a diagonal sum of these "family" SU(2)'s? To state this in another way, how far in energy does the e-μ universality (for example) extend? Are there more[59] Z^0's than just one, effectively differentially coupled to the e and the μ systems? (If there are, this will constitute mini-modifications of the theory, but not a drastic revolution of its basic ideas.)

In the next section I turn to a direct extrapolation of the ideas which went into the electroweak unification, so as to include strong interactions as well. Later I shall consider the more drastic alternatives which may be needed for the unification of all forces (including gravity)—ideas which have the promise of providing a deeper understanding of the charge concept. Regretfully, by the same token, I must also become more technical and obscure for the non-specialist. I apologize for this. The non-specialist may sample the flavour of the arguments with the next section (Sec. IV) ignoring the Appendices and then go on to Sec. V which is perhaps less technical.

IV. Direct Extrapolation from the Electroweak to the Electronuclear

4.1 *The three ideas*

The three main ideas which have gone into the electronuclear —also called grand-unification of the electroweak with the *strong* nuclear force (and, which date back to the period 1972-1974), are the following:

1. Frist: the psychological break (for us) of grouping quarks and leptons in the *same* multiplet of a unifying group G, suggested by Pati and myself in 1972.[60] The Group G must contain SU(2) × U(1) × $SU_C(3)$; must be non-Abelian, if all quantum numbers (flavour, colour, lepton, quark and family numbers) are to be automatically quantized and the resulting gauge theory asymptotically free.

2. Scond: an extension, proposed by Georgi and Glashow (1974)[61] which places not only (left-handed) quarks and leptons but also their antiparticles in the same multiplet of the unifying group.

Appendix I displays some examples of the unifying groups presently considered.

Now a gauge theory based on a "simple" (or with discrete symmetries, a "semi-simple") group G contains one basic gauge constant. This constant would manifest itself physically above the "grand unification mass" M, exceeding all particle masses in the theory—these themselves being generated (if possible) hierarchially through a suitable spontaneous symmetry-breaking mechanism.

3. The thrid crucial development was by Georgi, Quinn and Weinberg (1974)[62] who showed how, using renormalization group ideas, one could relate the observed low-energy couplings $\alpha(\mu)$, $\alpha_s(\mu)$ ($\mu \approx 100$ GeV) to the magnitude of the grand unifying mass M and the observed value of $\sin^2\theta(\mu)$; [$\tan\theta$ is the ratio of the U(1) to the SU(2) couplings].

4. If one extrapolates with Jowett,* that nothing essentially new can possibly be discovered—i.e. one assumes that there are no new features, no new forces, or no new "types" of particles to be discovered, till we go beyond the grand unifying energy M—then the Georgi, Quinn, Weinberg method leads to a startling result: this featureless "plateau" with no "new physics" heights to be scaled stretches to fantastically high energies. More precisely, if $\sin^2\theta(\mu)$ is as large as 0.23, then the grand unifying mass M cannot be smaller than 1.3×10^{13} GeV[63]. (Compare with Planck mass $m_P \approx 1.2 \times 10^{19}$

* The universal urge to extrapolate from what we know today and to believe that nothing new can possibly be discovered, is well expressed in the following:

"I come first, My name is Jowett
I am the Master of this College,
Everything that is, I know it
If I don't, it isn't knowledge"—

The Balliol Masque

GeV related to Newton's constant where gravity must come in.*) The result follows from the formula.[63, 64]

$$\frac{11\alpha}{3\pi}\ \ell n \frac{M}{\mu} = \frac{\sin^2\theta(M)-\sin^2\theta(\mu)}{\cos^2\theta(M)}\ , \qquad (I)$$

if it assumed that $\sin^2\theta(M)$—the magnitude of $\sin^2\theta$ for energies of the order of the unifying mass M—equals 3/8 (*see* Appendix II).

This startling result will be examined more closely in Appendix II. I show there that it is very much a consequence of the assumption that the $SU(2)\times U(1)$ symmetry survives intact from the low regime energies u right upto the grand unifying mass M. I will also show that there already is some experimental indication that this assumption is too strong, and that there may be likely peaks of new physics at energies of 10 TeV upwards.

4.2 *Tests of electronuclear grand unification*

The most characteristic prediction from the existence of the ELECTRONUCLEAR force is proton decay, first discussed in the context of grand unification at the Aix-en-Provence Conference (1973).[65] For "Semi-simple" unifying groups with multiplets containing quarks and leptons only, (but no antiquarks nor antileptons) the lepto-quark composites have masses (determined by renormalization group arguments), of the order of $\approx 10^5-10^6$ GeV.[66] For such theories the characteristic proton decays (proceeding through exchanges of *three* lepto-quarks) conserve quark number + lepton number, i.e. $P=qqq\rightarrow \ell\ \ell\ \ell$, $\tau_p\sim 10^{29}$ - 10^{34} years. On the contrary, for

* On account of the relative proximity of $M\approx 10^{13}$ GeV to m_p (and the hope of eventual unification with gravity), Planck mass m_p is now the accepted "natural" mass scale in Particle Physics. With this large mass as the input, the great unsolved problem of Grand Unification is the "natural" emergence of mass hierarchies (m_p, αm_p, $\alpha^2 m_p$,......) or $m_p \exp^{(-c_n/\alpha)}$, where c_n's are constants.

$$\frac{m_e}{m_p}\approx 10^{-22}$$

the "simple" unifying family groups like SU(5)[61] or SO(10)[67] (with multiplets containing antiquarks and anti-leptons) proton decay proceeds through an exchange of *one* Tepto-quark into an anti-lepton (*plus* pions, etc.) ($P \to \bar{\ell}$).

An intriguing possibility in this context is that investigated by Pati and myself for the maximal unifying group SU(16)—the largest group to contain a 16-fold fermionic family ($q, \ell, \bar{q}, \bar{\ell}$). This can permit four types of decay modes: $P \to 3\ell$ as well as $P \to \bar{\ell}$, $P \to \ell$ (e.g $P \to e^- + \pi^+ \pi^+ +$) and $P \to 3\ell$ (e.g. $N \to 3\nu + \pi^0$, $P \to 2\nu + e^+ + \pi^0$), the relative magnitudes of these alternative decays being model-dependent on how precisely SU(16) breaks down to $SU(3) \times SU(2) \times U(1)$. Quite clearly, it is the central fact of the existence of the proton decay for which the present generation of experiments must be designed, rather than for any specific type of decay modes.

Finally, grand unifying theories predict mass relations like:[68]

$$\frac{m_d}{m_e} = \frac{m_s}{m_u} = \frac{m_b}{m_\tau} \approx 2.8$$

for 6 (or at most 8) flavours *below the unification mass.* The important remark for proton decay and for mass relations of the above type as well as for an understanding of baryon excess[69] in the Universe,* is that for the present *these are essntially characteristic of the fact of grand unification—rather than of specific models.*

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*The calculation of baryon excess in the Universe—arising from a combination of CP and baryon number violations—has recently been claimed to provide teleological arguments for grand unification. For example, Nanopoulos[70] has suggested that the "existence of human beings to measure the ratio n_B/n_γ (where n_B is the numbers of baryons and n_γ the numbers of photons in the Universe) necessarily imposes severe bounds on this quantity: i.e. $10^{-11} \approx \left(\frac{me}{mp}\right)^{\frac{1}{2}} \leqslant n_B/n_\gamma \leqslant 10^{-4}$ ($\approx 0(\alpha^2)$)." Of importance in deriving these constraints are the upper (and lower) bounds on the numbers of flavours (≈ 6) deduced (1) from mass relations above, (2) from cosmological arguments which seek to limit the numbers of massless neutrinos, (3) from asymptotic freedom and (4) from numerous (one-loop) radiative calculations. It is clear that lack of accelerators as we move up in energy scale will force particle physics to reliance on teleology and cosmology (which in Landau's famous phrase is "often wrong, but never in doubt").

"Yet each man kills the thing he loves" sang Oscar Wilde anguishedly in his famous Ballad of the Reading Goal. Like generations of physicists before us, some in our generation also (through a direct extrapolation of the electroweak gauge methodology to the electronuclear)—and with faith in the assumption of no "new physics", which lead to a grand unifying mass $\sim 10^{13}$GeV—are beginning to believe that the end of the problems of elementarity as well as of fundamental forces is nigh. They may be right, but before we are carried away by this prospect, it is perhaps worth stressing that even for th simplest grand unifying model [Georgi and Glashow's SU(5) with just two Higgs (a $\underset{\sim}{5}$ and a $\underset{\sim}{24}$), the number of presently *ad hoc* parameters needed by the model is still unwholesomely large—22, to compare with 26 of the six-quark model based on the humble $SU(2)\times U(1)\times SU_C(3)$] We cannot feel proud.

V. Elementarity: Unification with Gravity and Nature of Charge

In some of the remaining parts of this lecture I shall be questioning two of the notions which have gone into the direct extrapolation of Sec. IV—first, do quarks and leptons represent the correct elementary* fields, which should appear in the matter Lagrangian, and which are structureless for renormalizability; second, could some of the presently considered gauge fields themselves be composite? This part of the lecture relies heavily on an address I was privileged to give at the European Physical Society meeting in Geneva in July this year.[64]

5.1 *The quest for elementarity, prequarks (preons and pre-preons)*

While the rather large number $\underset{\sim}{(15)}$ of elementary fields for the family group SU(5) already makes one feel somewhat uneasy, the number $\underset{\sim}{561}$, for example, proposed in the context of the three-family tribal group SU(11) or $\underset{\sim}{2048}$ for SU(22)

*I would like to quote Feynman in a recent interview to the *"Omni"* magazine: "As long as it looks like the way things are built with wheels within wheels, then you are looking for the innermost wheel—but it might not be that way, in which case you are looking for whatever the hell it is you find!". In the same interview he remarks "a few years ago I was very sceptical about the gauge theories... I was expecting mist, and now it looks like ridges and valleys after all."

(*see* Appx. 1) of which presumably $3 \times 15 = 45$ objects are of low and the rest of Planckian mass) is positively baroque. Is there any basic reason for one's instinctive revulsion when faced with these vast numbers of elementary fields.

The numbers by themselves would perhaps not matter so much. After all, Einstein in his description of gravity,[71] chose to work with *10* fields [$g_{\mu\nu}(x)$] rather than with just one (scalar field) as Nördstorm[72]) had done before him. Einstein was not perturbed by the multiplicity he chose to introduce, since he relied on the sheet-anchor of a fundamental principle—(the equivalence principle)—which permitted him to relate the 10 fields for gravity $g_{\mu\nu}$ with the 10 components of the physically relevant quantity, the tensor $T_{\mu\nu}$ of energy and momentum. *Einstein knew that nature was not economical of structures*: only of principles of fundamental applicability. The question we must ask ourselves is this: Have we yet discovered such principles in our question for elementarity, to justify having fields with such large numbers of components as elementary.

Recall that quarks carry at least three charges (colour, flavour and a family number). Should one not, by now, entertain the notions of quarks (and possibly of leptons) as being composites of some more basic entities* (PRE-QUARKS or PREONS), which each carry but *one* basic charge.[52]) These ideas have been expressed before but they have become more compulsive now, with the growing multiplicity of quarks and leptons. Recall that it was similar ideas which led from the eight-fold of baryons to a triplet of (Sakatons and) quarks in the first place.

The preon notion is not new. In 1975, among others, Pati, Salam and Strathdee[52] introduced 4 chromons (the fourth colour corresponding to the lepton number) and 4 flavours, the basic group being SU(8)—of which the family group $SU_F(4) \times SU_C(4)$ was but a subgroup. As an extension of these ideas, we now believe these preons carry magnetic charges and are bound together by very strong short-range forces, with quarks and leptons as their magnetically neutral composites.[73] The important remark in this context is that in a theory containing *both* electric and magnetic generalized charges, the ana-

*One must emphasise however that zero mass neutrinos are the hardest objects to conceive of as composites.

logues of the well-known Dirac quantization condition[74] gives relations like, $\frac{eg}{4\pi} = \frac{n}{2}$ for the strength of the two types of charges. Clearly, magnetic monopoles* $\left(g = \frac{4\pi n}{e}, \frac{e^2}{4\pi} = \frac{1}{137}\right)$ opposite polarity, are likely to bind much more tightly than electric charges, yielding composites whose non-elementary nature will reveal itself only for very high energies. This appears to be the situation at least for leptons if they are composites.

In another form the preon idea has been revived this year by Curtright and Freund,[52] who motivated by ideas of extended supergravity (to be discussed in the next subsection), reintroduce an SU(8) of 3 chromons (R, Y, B), 2 flavons and 3 familons (horrible names). The family group SU(5) could be a subgroup of this SU(8). In the Curtright-Freund scheme, the $\underset{\sim}{3} \times \underset{\sim}{15} = \underset{\sim}{45}$ fermions of SU(5)[61] can be found among the $\underset{\sim}{8} + \underset{\sim}{28} + \underset{\sim}{56}$ of SU(8) [or alternatively the $\underset{\sim}{3} \times \underset{\sim}{16} = \underset{\sim}{48}$ of SO(10) among the vectorial $\underset{\sim}{56}$ fermions of SU(8)]. (The next succession after the preon level may be the pre-preon level). It was suggested

DECADE	1950-1960	1960-1970	1970-1980	1980 →
Discovery in early part of the decade	The strange particles	The 8-fold way, Ω^-	Confirmation of neutral currents	W, Z, Proton decay
Expectation for the rest of the decade	—	SU(3) resonances	—	Grand Unification, Tribal Groups
Actual discovery	—	Hit the next level of elementarity with quarks	—	May hit the preon level, and composite structure of quarks

*According to 't Hooft's theorem, a monopole corresponding to the $SU_L(2)$ gauge symmetry is expected to possess a mass with the lower limit $\frac{m_W}{\alpha}$.[75, 76] Even if such monopoles are confined, their indirect effects must manifest themselves, if they exist. (Note that $\frac{m_W}{\alpha}$ is very much a lower limit for a grand unified theory like SU(5) for which the monopole mass is α^{-1} times the heavy lepto-quark mass.)

at the Geneva Conference[64] that with certain developments in field theory of composite fields it could be that just two pre-preons may suffice. But at this stage this is pure speculation.)

Before I conclude this section, I would like to make a prediction regarding the course of physics in the next decade, extrapolating from our past experience of the decades gone by:

5.2 *Post-Planck physics, supergravity and Einstein's dreams*

I now turn to the problem of a deeper comprehension of the charge concept (the basis of gauging)—*which, in my humble view, is the real quest of particle physics.* Einstein, in the last thirty-five years of his life lived with two dreams: one was to unite gravity with matter (the photon)—he wished to see the "base wood" (as he put it) which makes up the stress tensor $T_{\mu\nu}$ on the right-hand side of his equation $R_{\mu\nu}-\frac{1}{2}g_{\mu\nu}R=-T_{\mu\nu}$ transmuted through this union, into the "marble" of gravity on the left-hand side. The second (and the complementary) dream was to use this unification to comprehend the nature of electric charge in terms of space-time geometry in the same manner as he had successfully comprehended the nature of gravitational charge in terms of spacetime curvature.

In case some one imagines* that such deeper comprehension is irrelevant to quantitative physics, let me adduce the tests of Einstein's theory *versus* the proposed modifications to it (Brans-Dicke[77] for example). Recently (1976), the *strong* equivalence principle (i.e. the proposition that gravitational forces contribute equally to the inertial and the gravitational masses) was tested** to one part in 10^{12} [i.e. to the same accuracy as achieved in particle physics for $(g-2)_e$] through lunar-laser ranging measurements.[78] These measurements

*The following quotation from Einstein is relevant here. "We now realize, with special clarity, how much in error are those theorists who believe theory comes inductively from experience. Even the great Newton could not free himself from this error (Hypotheses non fingo)." This quote is complementary to the quotation from Einstein at the end of Sec. II.

**The *weak* equivalence principle (the proposition that all but the gravitational force contributes equally to the inertial and the gravitational masses) was verified by Eotvos to $1:10^8$ and by Dicke and Braginsky and Panov to $1:10^{12}$.

determined departures from Kepler equilibrium distances, of the moon, the earth and the sun to better than $\pm$ 30 cms. and triumphantly vindicated Einstein.

There have been four major developments in realizing Einstein's dreams:

(1) The Kaluza-Klein[79] miracle: An Einstein Lagrangian (scalar curvature) in five-dimensional space-time (where the fifth dimension is compactified in the sense of all fields being explicitly independent of the fifth co-ordinate) precisely reproduces the *Einstein-Maxwell* theory in four dimensions, the $g_{\mu 5}$ ($\mu = 0,1,2,3$) components of the metric in five dimensions being identified with the Maxwell field A_μ. From this point of view, Maxwell's field is associated with the extra components of curvature implied by the (conceptual) existence of the fifth dimension.

(2) The second development is the recent realization by Cremmer, Scherk, Englert, Brout, Minkowski and others that the compactification of the extra dimensions[80]—(their curling up to sizes perhaps smaller than Planck length $\leqq 10^{-33}$ cms. and the very high curvature associated with them)—might arise through a spontaneous symmetry breaking (in the first 10^{-43} seconds) which reduced the higher dimensional space-time effectively to the four-dimensional that we apprehend directly.

(3) So far we have considered Einstein's second dream, i.e. the unification of electromagnetism (and presumably of other gauge forces) with gravity, giving a space-time significance to gauge charges as corresponding to extended curvature in extra bosonic dimensions. A full realization of the first dream (unification of spinor matter with gravity and with other gauge fields) had to await the development of supergravity[81, 82] —and an extension to extra fermionic dimensions of superspace[83] (with extended torsion being brought into play in addition to curvature). I discuss this development later.

(4) And finally there was the alternative suggestion by Wheeler[84] and Schemberg that electric charge may be asso-

ciated with space-time topology—with worm-holes, with spacetime Gruyere-cheesiness. This idea has recently been developed by Hawking* and his collaborators.[85]

5.3 *Extended supergravity, SU(8) preons and composite gauge fields*

Thus far I have reviewed the developments in respect of Einstein's dreams as reported at the Stockholm Conference held in 1978 in this hall and organized by the Swedish Academy of Sciences.

A remarkable new development was reported during 1979 by Julia and Cremmer[87] which started with an attempt to use the ideas of Kaluza and Klein to formulate extended supergravity theory in a higher (compactified) spacetime—more precisely in eleven dimensions. This development links up, as we shall see, with preons and composite Fermi fields—and even more important—possibly with the notion of composite gauge fields.

Recall that simple supergravity[81] is the gauge theory of supersymmetry[58]—the gauge particles being the (helicity ± 2) gravitons and (helicity $\pm\frac{3}{2}$) gravitinos.** *Extended supergravity* gauges supersymmetry combined with SO(N) internal

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*The Einstein Lagrangian allows large fluctuations of metric and topology on Planck-length scale. Hawking has surmised that the dominant contributions to the path integral of quantum gravity come from metrics which carry one unit of topology per Planck volume. On account of the intimate connection (de Rham, Atiyah-Singer)[86] of curvature with the measures of space-time topology (Euler number, Pontryagin number) the extended Kaluza-Klein and Wheeler-Hawking points of view may find consonance after all.

* Supersymmetry algebra extends Poincare group algebra by adjoining to it supersymmetric charges Q_α which transform bosons to fermions. $(Q_\alpha, Q_\beta) = (\gamma_\mu P_\mu)_{\alpha\beta}$. The current which corresponds to these charges (Q_α and P_μ) are $J_{\mu\alpha}$ and $T_{\mu\nu}$ —these are essentially the currents which in gauged super-symmetry (i.e. supergravity) couple to the gravitino and the graviton, respectively.

symmetry. For N = 8, the tribal supergravity multiplet consists of the following SO(8) families:[81,87]

Helicity	± 2	$\underset{\sim}{1}$
	$\pm \frac{3}{2}$	$\underset{\sim}{8}$
	± 1	$\underset{\sim}{28}$
	$\pm \frac{1}{2}$	$\underset{\sim}{56}$
	0	$\underset{\sim}{70}$

As is well known, SU(8) is too small to contain SU(2) $\times$ U(1) $\times SU_C(3)$. Thus this tribe has no place for $W^{\mp}$ (though Z^0 and γ are contained) and no places for μ or τ or the t quark.

This was the situation last year. This year, Cremmer and Julia[87] attempted to write down the N = 8 supergravity Lagrangian explicitly, using an extension of the Kaluza-Klein ansatz which states that *extended supergravity* [with SO(8) internal symmetry] has the same Lagrangian in four space-time dimensions as *simple supergravity* in (compactified) eleven dimensions. This formal—and rather formidable ansatz—when carried through yielded a most agreeable bonus. *The supergravity Lagrangian possesses an unsuspected SU(8) "local" internal symmety* although one started with an internal SO(8) only.

The tantalizing questions which now arise are the following:

(1) Could this internal SU(8) be the symmetry group of the 8 preons (3 chromons, 2 flavons, 3 familons) introduced earlier?

(2) When SU(8) is gauged, there should be 63 spin-one fields. The supergravity tribe contains only 28 spin-one fundamental objects which are not minimally coupled. Are the 63 fields of SU(8) to be identified with composite gauge fields made up of the 70 spin-zero objects of the form $V^{-1}\,\partial\mu\,V$;

Do these composites propagate, in analogy with the well-known recent result in CP^{n-1} theories,[89] where a composite gauge field of this form propagates as a consequence of quantum effects (quantum completion)?

The entire development I have described—the unsuspected extension of SO(8) to SU(8) when extra compactified space-time dimensions are used—and the possible existence and quantum propagation of composite gauge fields—is of such crucial importance for the future prospects of gauge theories that one begins to wonder how much of the extrapolation which took $SU(2)\times U(1)\times SU_C(3)$ into the electronuclear grand unified theories is likely to remain unaffected by these new ideas now unfolding.

But where in all this is the possibility to appeal directly to experiment? For grand unified theories, it was the proton decay. What is the analogue for supergravity? Perhaps the spin 3/2 massive gravitino, picking its mass from a super-Higgs effect[90] provides the answer. Fayet[91] has shown that for a spontaneously broken globally supersymmetric weak theory the introduction of a local gravitational interaction leads to a super-Higgs effect. Assuming that supersymmetry breakdown is at mass scale m_W, the gravitino acquires a mass and an effective interaction, but of conventional weak rather than of the gravitational strength—an enhancement by a factor of 10^{34}. One may thus search for the gravitino among the neutral decay modes of J/ψ—the predicted rate being $10^{-3} - 10^{-5}$ times smaller than the observed rate for $J/\psi\to e^+e^-$ This will surely tax all the ingenuity of the great men (and women) at SLAC and DESY. Another effect suggested by Scherk[92] is anti-gravity—a cancellation of the attractive gravitational force with the force produced by spin-one gravi-photons which exist in all extended supergravity theories, Scherk shows that the Compton wave length of the gravi-photon is either smaller than 5 cms. or comprised between 10 and 850 metres in order that no conflict with what is presently known about the strength of the gravitational force.

Let me summarize: it is conceivable of course, that there is indeed a grand Plateau—extending even to Planck energies. If so, the only eventual laboratory for particle physics will be the Early Universe, where we shall have to seek for the answers

to that questions on the nature of charge. There may, however, be the indications of a next level of structure around 10 TeV; there are also beautiful ideas (like, for example, of electric and magnetic monopole duality) which may manifest at energies of the order of α^{-1} m_W (= 10 TeV). Whether even this level of structure will give us the final clues to the nature of charge, one cannot predict. All I can say is that I am for ever and continually being amazed at the depth revealed at each successive level we explore. I would like to conclude, as I did at the 1978 Stockholm Conference, with a prediction which J.R. Oppenheimer made more than twenty-five years ago and which has been fulfilled today in a manner he did not live to see. More than anything else, it expresses the faith for the future with which this greatest of decades in particle physics ends: "Physics will change even more...If it is radical and unfamiliar...we think that the future will be only more radical and not less, only more strange and not more familiar, and that it will have its own new insights for the inquiring human spirit.".

J.R. Oppenheimer Reith Lectures, BBC, 1953

APPENDIX I

EXAMPLES OF GRAND UNIFYING GROUPS

	Multiplet	**Exotic guage particles**	**Proton decay**
Semi-simple groups*) (with left-right symmetry) Example $[SU(6)_F \times SU(6)_c]_{L \to R}$	$G_L \to \begin{bmatrix} q \\ \ell \end{bmatrix}_L , G_R \to \begin{bmatrix} q \\ \ell \end{bmatrix}_R$ $G = G_L \times G_R$	Lepto-quarks$\to(\bar{q}\,\ell)$ Unifying mass$\approx 10^6$ MeV	Lepto-quarks $\to$ W $+$ (Higgs) or Proton $=$ qqq$\to \ell\ \ell\ \ell$
Simple groups Examples Family groups$\to$ {SU(5) or SO(10)} $\downarrow$ $\downarrow$ Tribal groups$\to$ {SU(11) SO(22)}	$G \to \begin{pmatrix} q \\ \ell \\ \hline \bar{q} \\ \bar{\ell} \end{pmatrix}_L$	Diquarks $\to$ (qq) Dileptons $\to(\ell\ \ell)$ Lepto-quarks$\to(\bar{q}\,\ell)$, $(q\,\ell)$ Unifying mass$\approx 10^{13}$-10^{15} GeV	qq $+ \bar{q}\,\ell$ i.e. Proton P $=$ qqq$\to \bar{\ell}$ Also possible, $P \to \ell$, $P \to 3\bar{\ell}$, $P \to 3\ell$

* Grouping quarks (q) and leptons (l) together, implies treating lepton number as the fourth colour, i.e. $SU_C(3)$ *extends to* $SU_C(4)$ (Pati and Salam).[93] A Tribal group, by definition, contains all known families in its *basic representation. Favoured representations* of Tribal SU(11) (Georgi)[94] and Tribal SO(22) (Gell-Mann[95] *et al.*) contain 561 and 2048 *fermions!*

APPENDIX II

The following assumptions went into the derivation of the formula (I) in the text.

(a) $SU_L(2)\times U_{L,\,R}(1)$ survives intact as the electroweak symmetry group from energies $\approx u$ right upto M. This intact survival implies that one eschews, for example all suggestions that: (i) low-energy $SU_L(2)$ may be the diagonal sum of $SU_L^{I}(2)$ $SU_L^{II}(2)$, $SU_L^{III}(2)$, where I, II, III refer to the (three?) known families; (ii) or that the $U_{L,\,R}(1)$ is a sum of pieces, where $U_R(1)$ may have differentially descended from a (V+A) symmetric $SU_R(2)$ contained in G, or (iii) that U(1) contains a piece from a four-colour symmetry $SU_c(4)$ (with lepton number as the fourth colour) and with $SU_c(4)$ breaking at an intermediate mass scale to $SU_c(3)\times U_c(1)$.

(b) The second assumption which goes into the derivation of the formula above is that there are no unexpected heavy fundamental fermions, which might make $\sin^2\theta(M)$ differ from $\frac{3}{8}$ — its value for the low mass fermions presently known to exist.*

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* If one does not know G, one way to infer the parameter $\sin^2\theta$ (M) is from the formula;

$$\sin^2\theta(M) = \frac{\Sigma T^2_{3L}}{\Sigma Q^2}\left[= \frac{9\,N_q + 3\,N_l}{20N_q + 12\,N_l}\right].$$

Here N_q and N_e are the numbers of the fundamental quark and lepton SU(2) doublets (assuming these are the only multiplets that exist). If we make the further *assumption* that $N_q = N_e$ (from the requirement of anomaly cancellation between quarks and leptons) we obtain $\sin^2\theta(M)=\frac{3}{8}$. This assumption however is not compulsive; for example anomalies cancel also if (heavy) mirror fermions exist.[98] This is the case for $[SU(6)]^4$ for which $\sin^2\theta(M)=\frac{9}{28}$

(c) If these assumptions are relaxed, for example, for the three family group $G = [SU_F(6) \times SU_c(6)]_{L \to R}$, where $\sin^2\theta(M) = \frac{9}{28}$, we find the grand unifying mass M tumbles down to 10^6 GeV.

(d) The introduction of intermediate mass scales [for example, those connoting the breakdown of family universality, or of left-right symmetry, or of a breakdown of 4-colour $SU_c(4)$ down to $SU_c(3) \times U_c(1)$] will as a rule push the magnitude of the grand unifying mass M upwards.[96] In order to secure a proton decay life, consonant with present empirical lower limits ($\sim 10^{30}$ years)[97] this is desirable anyway. τ_{proton} for $M \sim 10^{13}$ GeV is unacceptably low $\sim 6 \times 10^{23}$ years unless there are 15 Higgs). There is from this point of view, an indication of there being in Particle Physics one or several intermediate mass scales which can be shown to start from around 10^4 GeV upwards. *This is the end result which I wished this Appendix to lead upto.*

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12. Professor John Ziman, F.R.S., on "Professor Abdus Salam", dated 2nd July 1981.

PROFESSOR ABDUS SALAM

Mr. Vice-Chancellor,

"Only connect!". That is the theme that runs through the life and work of Abdus Salam. He has followed the teaching of Islam, and has dedicated his life to the principle of unity—the unity of Nature and the unity of Mankind. As a natural philosopher he has seen that the various interactions of the elementary particles must be no more than diverse aspects of a single primary force. As a political and moral leader he has demonstrated that the various interactions of nations and cultures are no obstacle to the brotherhood of Man in science.

In the Faculty of Science, we honour him as one of the finest theoretical physicists in the world. In 1950, he was awarded the Smith's Prize at Cambridge, for an outstanding *pre*-doctoral contribution to physics. Since then he has been continually at the working face of the deepest mine that science has ever pushed down into the bedrock of reality. He has had a major part in every act of the unfolding drama of the discovery and understanding of the primary entities of quantum physics. It is astonishing that a man who is also so active in public affairs should have published some 200 papers on the physics of elementary particles, and is still forging ahead in that intensely competitive and dynamic intellectual enterprise.

In fact, he is still so hard at it that I have not dared to engrave a tablet of his achievements in physics: tomorrow morning, a new experimental observation somewhere might add a whole new theory to the list. Salam has the great scientific gift of suggesting new, physically realistic, theoretical connections that are really worth the effort to confirm. The great theory of the electroweak force, for which he shared the 1979 Nobel Prize in physics, was first put forward 13 years ago. For the next three or four years it was totally neglected, because of apparently insuperable mathematical difficulties. When these had eventually been cleared away, some very delicate experi-

ments were still needed to test the mathematical predictions against physical reality. I remember visiting him in Trieste at the exciting period, with telephone calls from continent to continent to check up on data that seemed, at first, to disconfirm his cherished hypothesis. Salam's personal enthusiasm for physics is delightfully infectious. It was a happy day for us, too, when his persistence was rewarded, and it came out right after all.

What that theory did was to show that certain well-known interactions between elementary particles—for example, the so-called 'weak' force that eventually drives every neutron to decay into a proton and an electron—could be treated as part of the much more familiar electromagnetic force that acts between all charged particles. It was a hard nut to crack. Compared with some of your modern mathematical physicists, Salam's methods are slightly old fashioned. But he uses such magic sledgehammers as gauge fields and renormalization theory with a delicate, practised hand. Faraday and Maxwell would have been delighted with his achievement, which is a bit like their unification of magnetism itself with electricity, more than a century ago.

It is good to see science unfolding in the traditional manner. That was a scientific breakthrough in the old style. It has opened the way to yet another revolution in quantum physics, with the goal of a grand unification of all the forces of Nature now in clear sight. Perhaps this is only a mirage—or perhaps another of Abdus Salam's imaginative schemes for the ultimate construction of matter and energy has got it right, and will again be confirmed by the observation of a predicted physical phenomenon that cannot otherwise be explained.

One such prediction of his current theories is that protons themselves, the building blocks of all heavy matter in the universe, should not live forever. Just like neutrons, they should eventually be driven to transform themselves, into lighter particles and radiation, by a tiny component of a universal force. Fortunately, it is a very small effect. Our present-day protons should last a billion, billion times as long as the universe has already existed—which is surely a little longer than it might take—for me to master all of Salam's theories, fully,

for myself, and then explain them very carefully to this assembly.

Perhaps, Mr. Vice-Chancellor, you will forego that pleasant exercise, and accept his world-wide scientific reputation as evidence of his eminent worthiness for an honorary doctorate in this Faculty. But first, let me present Abdus Salam to you in another aspect, as one of the first citizens of the World. He might be considered as just a leading British scientist, having been Professor of Theoretical Physics at Imperial College, in the University of London, for more than 20 years. But in fact he spends a good deal of his time in Trieste, in Italy, and is a frequent visitor to the United Nations, in New York. He is a sort of one-man multi-national corporation busily transferring intellectual technology to the less developed countries of the world.

His homeland is Pakistan, a country to which he remains deeply attached. He was born and brought up in the city of Jhang, not far from Lahore, that ancient paradise of Moghul palaces and gardens. From Government College, Lahore, a scholarship transported him to Cambridge, where he showed his mastery of all the mathematics and all the physics that any undergraduate could be permitted to study, and soon had his feet on the swiftly-rising escalator of research. On that brilliant early achievement and promise, he went back to Lahore as a Full Professor at the very tender age of 25. In fact, by ordinary standards of academic success, he was now all set for a comfortable career.

But the next three years must have been the most miserable—and formative—of his life. The old Government College was previously one of the leading academic institutions of British India—but there was little interest in scientific research. As Salam recounts it, the head of the college offered him the choice of three college jobs for any spare time he might have after his teaching duties. He could become warden of the college hostel, or chief treasurer of its accounts, or, if he liked, he could become president of its football club. He says he was fortunate to get the football club—though I suspect that rival clubs didn't feel that way!

The most severe deprivation of those years was the loss of contact with fellow scientists working on the exciting problems

of the day. As he analysed it later, this was one of the main reasons for the dispirited research atmosphere in almost all the less developed countries. I quote:

"Gifted men, from countries such as Pakistan, Brazil, Lebanon or Korea, work in advanced countries in the West or the Soviet Union. They then go back to build their own indigenous schools. When these men go back to the universities in their home countries, they were perhaps completely alone: the groups, of which they formed a part, were too small to form a critical mass; there were no good libraries; there was no communication with groups abroad. There was no criticism of what they were doing; new ideas reached them too slowly; their work fell back within the grooves of what they were doing before they left the stimulating environments of the institutions at which they had studied in the West or the Soviet Union. These men were isolated, and isolation in theoretical physics—as in most fields of intellectual work—is death. This was the pattern when I became associated with Lahore University!".

Even a thoroughly self-winding genius, such as a young Salam, could not accept this danger of being slowly buried alive. In 1954 he came back to England, and was soon established in his chair in London. Although he never lost his close personal and professional contacts with his home country, and he takes special pride in being the first Pakistani to win a Nobel Prize, he has not returned to a regular academic appointment in that country.

But Abdus Salam is a man whose heart is as great as his mind. The memory of those anguished years of isolation did not turn sour within him: it became the creative kernel of his greatest achievement. He vowed to provide the means by which other talented young scientists, from less developed countries, could keep themselves from scholarly death by isolation, without having to desert their native lands.

A single line in his biodata records that he has been Director of the International Centre for Theoretical Physics at Trieste since 1964. There is more in that title than the fifty awards he has won from universities and national academies around the world. He created that Centre out of nothing: it is now one of the most successful and respected international institutions of

our times. Scientists from developing countries come to Trieste to get the latest scientific news, to learn the latest techniques, and to meet their colleagues from both advanced and developing countries. They come to attend advanced courses, or to work quietly in the library, to argue vehemently with some very bright young chap from Indonesia, or to acquire understanding and insight from a very wise old Professor from Sweden. It is a bustling railway junction of the intellect, bursting out of the handsome buildings it acquired only a few years ago, managed by the brilliant improvisations of a devoted staff, and always short of funds. Yet it lives, and works, and grows, and serves the whole world of the physical sciences.

How was it done? How did that most abstruse of young professors persuade the hard-headed delegates of lumbering international organisations such as the International Atomic Energy Agency and UNESCO, to put their money into such an out-of-the-way project? How did he so befriend the Italian Government that they gave such a support in cash and kind. In these past few years of declining funds and proliferating bureaucracy, how has the Centre managed to remain alive, and flourishing, in the interstices of a system that has brought much grander projects to frustration?

The Trieste Centre was created, and continues to thrive, through a singular force—the personal will power of its Director. Let me warn you, Mr. Vice-Chancellor, that Abdus Salam is a manifestation of that imaginary concept of mechanics—the irresistible force Suppose he asks you to do a little favour for him — say a three-week visit to the University of Vladivostock. You will find you have only three possible responses. The first is: "But Abdus that's completely forbidden by my religion. I shall be damned to eternity if I go to Vladivostock in August". The second is: "Very sorry, old chap, but all that month I'm absolutely committed to lecturing in Bogota". Most commonly, however, the only remaining degree of freedom is: "Yes—how do I get there?", and off you go. He seems to have that effect on everyone he meets—politicians, government officials, international bureaucrats and fellow scientists. He impresses and persuades by the integrity, purity and singleness of his purpose, put into the service of his fellow men.

Originally, the Trieste Centre was for the highest of pure science, setting standards of excellence for Third World physics at the most advanced level. But Salam's own experience, both in directing the Centre and as a participant in science policy-making for successive governments of Pakistan from about 1960 to 1974, taught him to widen the objectives of science for countries struggling for economic and social development. Over the years, the programme of associateships, advanced courses, seminars, workshops and conferences at Trieste has broadened, to foster and coordinate research in all fields of applicable science. Salam speaks now for the special role of the trained scientist in this development process and for the need for national and international scientific institutions which will make that role attractive and productive. He has thrown his personal charisma, and the immense prestige of his Nobel Prize into a world-wide campaign to establish the essential infrastructure, that can give aid and advice to the smallest and poorest nations in their efforts towards self-development.

In both spheres of philosophy, natural and social, Abdus Salam strives continually to 'connect'. Along that way he has already achieved such a unification of Nature, such a realisation of the ideal of human brotherhood, that it is very propeı that we should do him honour. Mr. Vice-Chancellor, to present to you Abdus Salam as eminently worthy of the degree of Doctor of Science—*honoris causa.*

13. List of Universities which awarded the Honorary Degree of Doctor of Science to Abdus Salam.

(i)	Panjab University, Lahore ..	1957
(ii)	University of Edinburgh, Edinburgh	1971
(iii)	University of Trieste, Trieste	1979
(iv)	University of Islamabad, Islamabad ..	1979
(v)	Universidad Nacional de Ingenieria, Lima ..	1980
(vi)	University of San Marcos, Lima ..	1980
(vii)	National University of San Antonio, Abad, Cuzco	1980
(viii)	Universidad Simon Bolivar, Caracas ..	1980
(ix)	Yarmouk University, Yarmouk ..	1980
(x)	University of Istanbul, Istanbul	1980
(xi)	Charles University	1980
(xii)	University of Wroclaw	1981
(xiii)	University of Bristol	1981

14. List of Distinguished Awards won by Abdus Salam.

(i) Hopkins Prize, Cambridge University, for the most outstanding contribution to Physics, during 1957-58 1958

(ii) Adams Prize, Cambridge University 1958

(iii) Sitara-i-Pakistan, S.PK. .. 1959

(iv) Pride of Performance Medal and Award .. 1959

(v) First recipient of Maxwell Medal and Award, Physical Society, London .. 1962

(vi) Hughes Medal, Royal Society, London .. 1964

(vii) Atoms for Peace Medal and Award, Atoms for Peace Foundation 1968

(viii) J. Robert Oppenheimer Memorial Medal and Prize, University of Miami 1971

(ix) Guthrie Medal and Prize, Institute of Physics, London 1976

(x) Sir Devaprasad Sarvadhikary Gold Medal, Calcutta University 1977

(xi) Matteuci Medal, Accademia Nazionale di XL, Rome 1978

(xii) John Torrence Tate Medal, American Institute of Physics 1978

(xiii) Royal Medal, Royal Society, London .. 1978

(xiv) Nishan-e-Imtiaz, Pakistan 1979

(xv) Nobel Prize for Physics, Nobel Foundation .. 1979

(xiv) Einstein Medal, UNESCO, Paris .. 1979

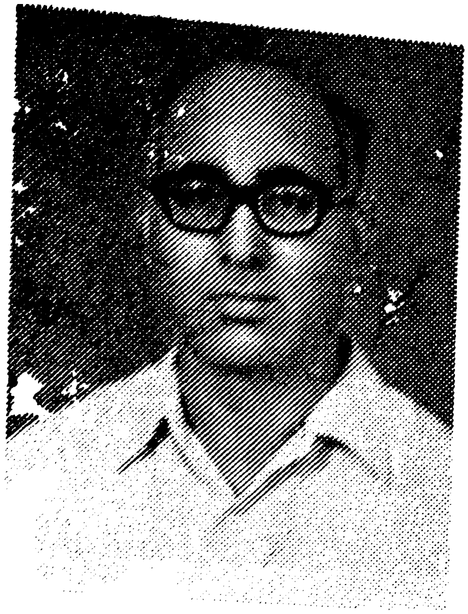
(xvii) Shri R.D. Birla Award, Indian Physics Association 1979

(xviii) Order of Andres Bello, Venezuela .. 1980

(xix) Josef Stefan Medal, Ljubliana 1980

15. List of prominent Societies which have elected Abdus Salam as a Fellow or a Member.

(i)	Elected Fellow of the Royal Society, London, as the youngest, 33, Member	1959
(ii)	Fellow of the Royal Swedish Academy of Sciences	1970
(iii)	Foreign Member of the American Academy of Arts and Sciences	1971
(iv)	Foreign Member of the USSR Academy of Sciences	1971
(v)	Honorary Fellow of St. John's College, Cambridge	1971
(vi)	Foreign Associate of the USA National Academy of Sciences	1979
(vii)	Foreign Member of the Accademia Nazionale dei Lincei, Rome	1979
(viii)	Foreign Member of the Accademia Tiberina, Rome	1979
(ix)	Foreign Member of the Iraqi Academy ..	1979
(x)	Honorary Fellow of the Tata Institute of Fundamental Research, Bombay	1979
(xi)	Honorary Member of the Korean Physics Society, Seoul	1979
(xii)	Foreign Member of the Academy of the Kingdom of Morocco	1980
(xiii)	Foreign Member of the Accademia Nazionale delle Scienze dei XL, Rome	1980
(xiv)	Member of the European Academy of Science, Arts and Humanities, Paris	1980
(xv)	Associate Member of the Josef Stefan Institute, Ljubliana	1980



About the Author

Abdul Ghani, born in an agriculturist Waraich family in Sargodha in December 1925, struggled to get his M.Sc. from the Panjab University in 1950. He taught Physics at Islamia College, Lahore from 1948 to 1954, won his M.Sc. in Nuclear Physics from London University in 1957, started post-graduate experimental research, as a Ph.D. student from University College, London (i.e. UCL), at the Synchro-Cyclotron Accelerator of the European Organisation For Nuclear Research (i.e. CERN), Geneva where he first met and developed close friendship with Professor Abdus Salam who used to visit CERN at that time.

Dr. Ghani was appointed Research Assistant in the Physics Department of University College, London during 1959-60, obtained his Ph.D. in 1960, worked as a visiting Scientist (the first from Indo-Pakistan) at CERN during 1961-63, became the first Director of Pakistan Institute of Nuclear Science and Technology (i.e. PINSTECH), NILORE, Islamabad in 1966, and went to United States as a visiting Professor to Virginia Polytechnic Institute during 1968-70. He was inducted by the Federal Government as a Member, Federal Public Service Commission which he served from 1972 to 1976 and then was appointed the Chairman, Pakistan Council of Scientific and Industrial Research (i.e. PCSIR) for the period 1976 to 1980.

He has published a large number of papers and articles including ones on the role of science and technology in the promotion of economic development in Third World countries, with special reference to Peoples Republic of China.